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DEPARTMENT OF DEFENSE MATERIALS CONSUMPTION AND THE IMPACT OF MATERIAL AND ENERGY RESOURCE SHORTAGES

Mark D. Levine, et al

Stanford Research Institute

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DEPARTMENT OF DEFENSE MATERIALS CONSUMPTION AND THE IMPACT OF MATERIAL AND ENERGY RESOURCE SHORTAGES

By: Mark D. Levine and Irving W. Yabroff

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The Department of Defense and U.S. consumption of 17 material and energy resources in 1972 is estimated using input-output techniques. The contribution of individual industries to this consumption is presented in the form of flow diagrams. A linear program is added to the input-output formulation to estimate the economic impacts of shortages of each resource.

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ILLUSTRATIONS

ILLUSTRATIONS (concluded)

TABLES

I INTRODUCTION

This is the final report of the Stanford Research Institute (SRI) study of Department of Defense (DoD) materials consumption. One objective of the study was to describe the direct and indirect consumption of selected materials by DoD so as to illuminate the key dependencies of DoD on industrial sectors of the economy for the provision of final demand products. This dependency would become critical in the event of material shortages. Thus, a second objective of the study was to analyze the economic impacts of potential material shortages on the capability of U.S. industry to meet DoD final demand requirements.

This report is presented in order of the above objectives. Section II is a brief summary of the findings and accomplishments of the study. Section III describes the U.S. and DoD materials flow. Section IV presents the results of the analysis of the impact of materials shortages. Detailed inputs and results are included in the appendix.

II SUMMARY

The purpose of this research was twofold: (1) to develop estimates of the amount of each of 17 critical materials consumed by U.S. industry to supply DoD final demand and to describe their direct and indirect flow through industry and (2) to analyze potential economic impacts of a shortage of one or more of these materials.

A. DoD Materials Consumption

The methodology used to estimate DoD materials consumption was based on the use of national tables of interindustry purchases and sales provided by the Bureau of Economic Analysis, U.S. Department of Commerce, and information on the consumption of each material by each U.S. industry. The flow of material through an industry can be best understood by referring to Figure II-1, which represents the material consumption requirements of an industry and its final demand. As Figure II-1 shows, material is

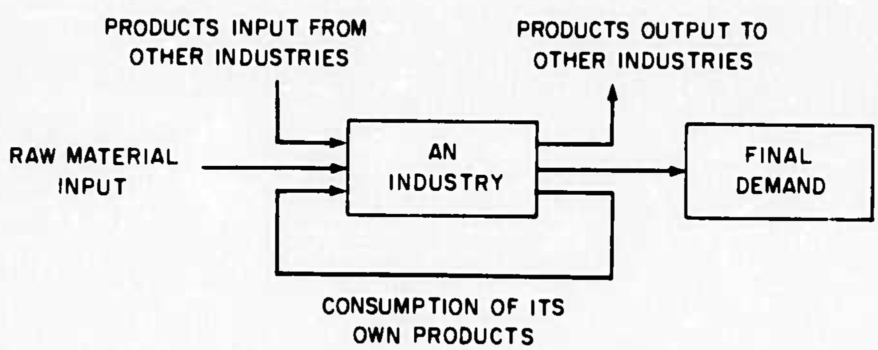

FIGURE II-1. REPRESENTATION OF MATERIAL CONSUMPTION REQUIREMENTS OF AN INDUSTRY AND ITS FINAL DEMAND

transferred to an industry from the material source industry, labeled "raw material input." The source industry is a material refining or fabricating industry. The receiving industry is a manufacturing industry, which converts the material into products. These products are distributed or sold to three outlets: the ultimate consumer, such as DoD; other industries that require them as inputs to manufacture their own products; and itself. These three outlets are referred to as final demand, intermediate demand, and self-consumption. Furthermore, as indicated in Figure II-1, an industry also receives products from other industries that have consumed the material in their manufacture. Since the total material required as inputs to an industry is equal to that required for the outputs, the description shown in the figure can be generalized to describe the total flow of materials throughout the U.S. economy.

Material consumption anf low analysis was performed for the following materials:

Aluminum	Natural gas	Titanium metal
Chromium	Nickel	Titanium pigment
Coal	Petroleum	Tungsten
Cobalt	Platinum	Zinc castings
Copper	Silver	Zinc galvanizing
Lead	Tin	

Two important assumptions of this calculation of material flow are:

1. The material flow considered is that consumed by industry and does not include that sold directly to final demand. For the metals, the material not considered is primarily that exported. For the energy resources, the significant amount consumed by the household and transportation sectors of final demand was not included.

2. No distinction is made between the products of an industry sold to DoD and those sold to the civilian economy. This assumed homogeneity of products may be inaccurate for some specialized industries, such as aircraft and electronics.

Several forms of display for the voluminous and complex results of the calculations were developed. One of the most useful is the computerized flow diagram, an example of which is shown in Figure II-2. This figure shows the consumption of aluminum (in hundreds of short tons) by industry for DoD final demand. The six industries whose final demand products require the most aluminum are shown in Figure II-2, and the remaining industries are aggregated to the category "other." Symbols representing each industry have been used to indicate the component flow of products and consumption of materials as previously described in Figure II-1. Thus the quantity labeled "material source" in Figure II-2 corresponds to that labeled "raw material input" in Figure II-1. Similarly, the quantity labeled "total requirements for final demand" corresponds to "final demand" in Figure II-1. The other labels are self-explanatory. The computerized flow diagram indicates that indirect consumption is a major factor in total aluminum requirements. Thus the direct consumption of raw material by all six of the industries shown is significantly less than the total consumption required for their final demands by DoD.

Another form of display, which presents less detail, is the circle diagram, an example of which is shown in Figure III-3. The percentage of total aluminum consumption required for each of the final demand products that consume the most aluminum is shown for the total United States and for DoD. This figure indicates that significant differences exist between the products that require large fractions of aluminum consumption for DoD and those for the nation as a whole.

An example of a display that provides a comparison of all 17 materials is presented in Table II-1, which shows the percentage of U.S. and DoD consumption that is direct versus indirect, and DoD consumption as a percentage of the total U.S. consumption. Tables that show the percentage of U.S. and DoD consumption of each of the 17 materials by each of the 150 industries or sectors of the economy are included in Section III. These tables provide a visual recognition of those sectors that are important contributors to U.S. and DoD consumption for many or all of the materials.

Flow diagrams and circle charts for U.S. and DoD consumption for all 17 materials are included in the appendix.

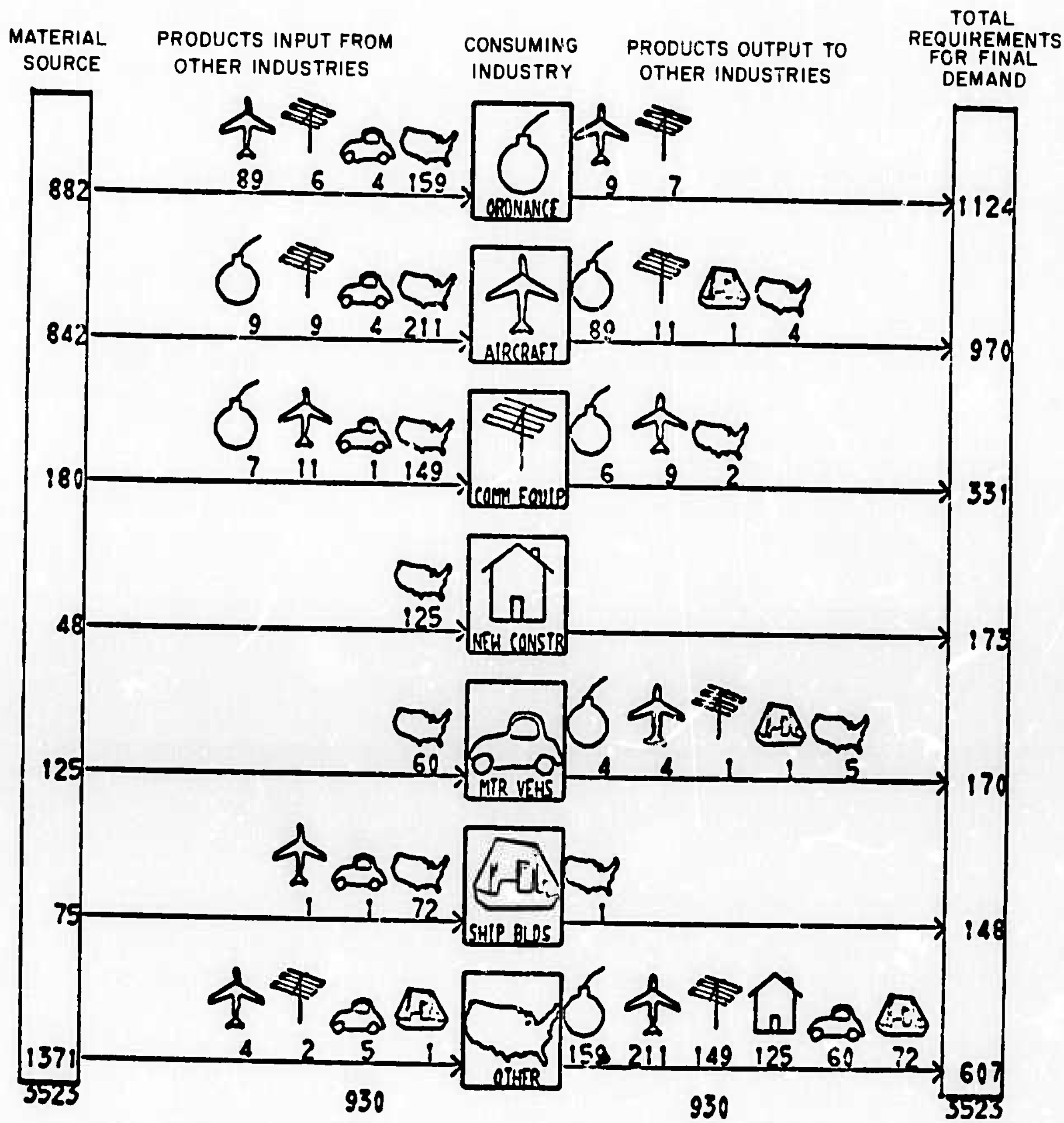

FIGURE II-2. 1972 ALUMINUM CONSUMPTION BY THE DOD
(Hundred Short Tons)

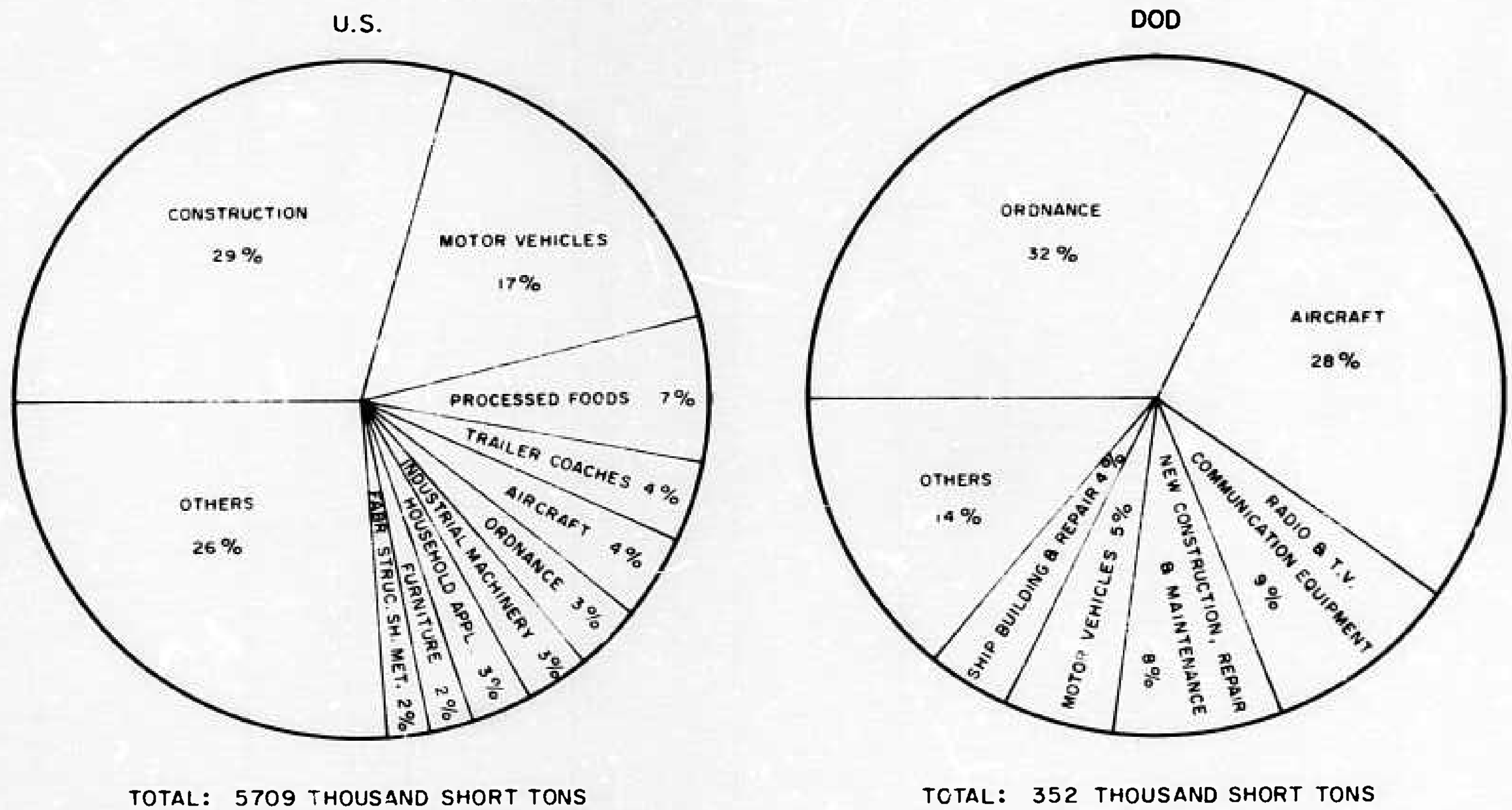

FIGURE II-3 . U.S. AND DOD CONSUMPTION OF ALUMINUM BY END USE (1972)

Table II-1

CONSUMPTION PERCENTAGES FOR 17 MATERIALS
(1972)

Material	Percentage of Consumption that is Direct		DoD Consumption as a Percentage of U.S. Total
	U.S.	DoD	
Aluminum	37%	53%	6%
Chromium	31	42	5
Coal	35	18	3*
Cobalt	12	11	5
Copper	42	46	5
Lead	48	64	8
Natural gas	39	32	3*
Nickel	43	57	8
Petroleum	37	45	4*
Platinum	31	36	4
Silver	42	31	3
Tin	4	4	4
Titanium metal	67	72	41
Titanium pigment	15	8	3
Tungsten	34	34	9
Zinc castings	68	69	4
Zinc galvanizing	22	8	4

*The energy resources have significant sales directly to final demand which are not included in these figures, as was discussed previously. Thus while only 4 percent of petroleum is consumed by industry for DoD, approximately 5 percent of total U.S. petroleum is consumed by DoD.

B. Material and Energy Resource Shortages

The second part of the study investigated economic impacts of shortages of material and energy resources. The objective of the economic analysis of shortages was to determine and analyze:

- the effects of specific resource shortages on GNP, and the relative sensitivity of GNP to shortages of different resources
- the effect on GNP of reducing both civilian and DoD final demand for the outputs of specific industrial sectors during resource shortages
- the effects on GNP of a simultaneous shortage of more than one resource
- the effects of possible shortages on DoD needs for materials and energy resources.

The basic approach of the shortage analysis was first to characterize the effects of the shortage on the U.S. economy and then to investigate the implications of these economic effects on DoD materials consumption.

The methodology for investigating economic impacts of shortages combined the input-output table of the first part of the study with a linear programming approach.* The linear programming formulation, structured to maximize GNP, was used to simulate the allocation of resources under shortage conditions. An important limitation of the linear programming methodology was the exclusion of the effects of material substitution in reducing economic impacts of shortages. The most significant methodological problem encountered in applying the model was the establishment of minimum final demand constraints for industrial output.† Analysis of historical

---

*For most of the calculations, the input-output table was aggregated to 37 sectors. Results for the 37 sector table agreed well with calculations using a 150 sector input-output table.

†Final demand constraints are needed to assure that the linear programming solution does not reduce final demand for the products of specified industries so low as to threaten the viability of these industries.

patterns of final demand for industrial products provided a solution to this problem.

The results of the analysis are summarized below.

1. Effects of Shortages on GNP

Figure II-4 summarizes the estimated GNP reduction associated with shortages of varying magnitude for a series of material and energy resources. Although the curves are only approximate, they are useful in providing rough estimates of effects of shortages on GNP and are especially useful for comparing the relative economic impacts of shortages of different materials. From the information in Figure II-4 (and analysis of the economic impacts of shortages of several other materials), we conclude that:

- The adverse economic effects of energy shortages occur at lower shortage levels and are greater than the effects of material resource shortages. This is probably due to the ubiquity of energy in the economy.
- For most materials, relatively small shortages (5-15 percent of consumption) are likely to have only localized economic effects. Greater shortages are likely to produce adverse economic effects of substantially increasing magnitude.
- Under shortage conditions, those material resources most likely to reduce GNP, in decreasing order of impact, are platinum, cobalt, tin, chromium, aluminum, copper, silver, and nickel.

2. Simultaneous Shortages of Two Resources

Figure II-5 compares the effects of a simultaneous aluminum and petroleum shortage with shortages of the two materials occurring separately. The simultaneous shortages have a lesser economic impact than the sum of the separate shortage impacts. This is a result of the fact that a shortage of one resource diminishes demand for other resources by reducing economic activity.

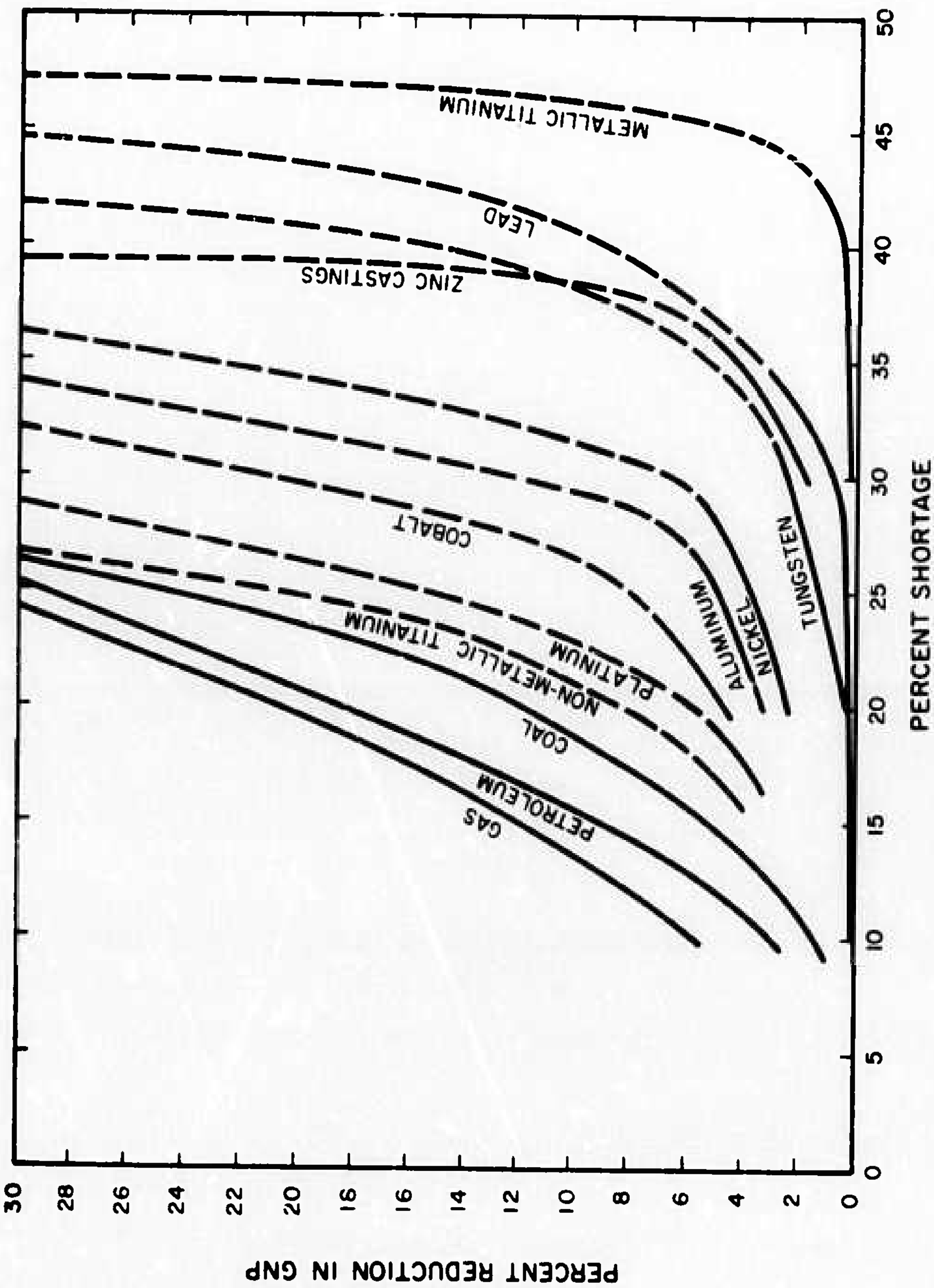

FIGURE II - 4. EFFECTS OF ENERGY AND MATERIAL SHORTAGES ON GNP

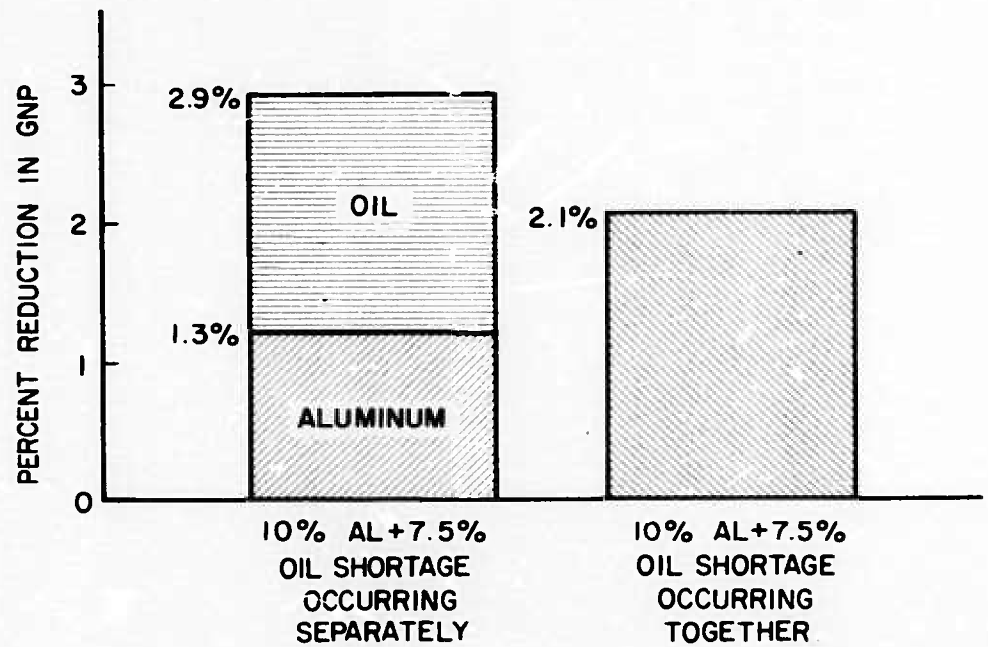

FIGURE II-5. EFFECTS OF SIMULTANEOUS ALUMINUM AND OIL SHORTAGES

3. <u>Reductions in Final Demand To Minimize Adverse Economic Effects of Shortages</u>

During an aluminum shortage, reducing final demand for the industrial products shown in Figure II-6 is most likely to minimize the adverse effects of the shortage on GNP, as the industries manufacturing these products contribute least to GNP through the use of aluminum. Also shown in Figure II-6 is the percentage of DoD and U.S. aluminum use through consumption of the specific products. An important conclusion from this figure is that, in the event of an aluminum shortage, availability of ammunition to DoD is likely to be substantially reduced, as (1) the ammunition industry contributes little to GNP through the use of aluminum and consequently economic forces would tend to divert the aluminum to other industries, and (2) DoD consumes a substantial quantity of aluminum through its purchases of ammunition. Similar results and analyses are contained in the report for other material and energy resources.

4. <u>Recommendations</u>

The major recommendations and conclusions of the study are:

- Among the resource shortages analyzed, the economic impacts of energy shortages are particularly adverse. The availability of these resources deserves continuing priority attention by DoD.

- Among the material resources studied, chromium, aluminum, and tin are commodities for which a stockpile for economic purposes may be desirable, because of potentially adverse economic impacts of shortages of these materials, high levels of imports, insecurity of import sources, and limited domestic reserves. Platinum is also a candidate for an economic stockpile or alternative measures to assure supply, especially because of its economic impacts at relatively low shortage levels. Additional analysis of measures to protect against adverse impacts of shortages of these materials is recommended.

- A framework has been established to guide DoD advance planning for shortages. One example of the results of applying this

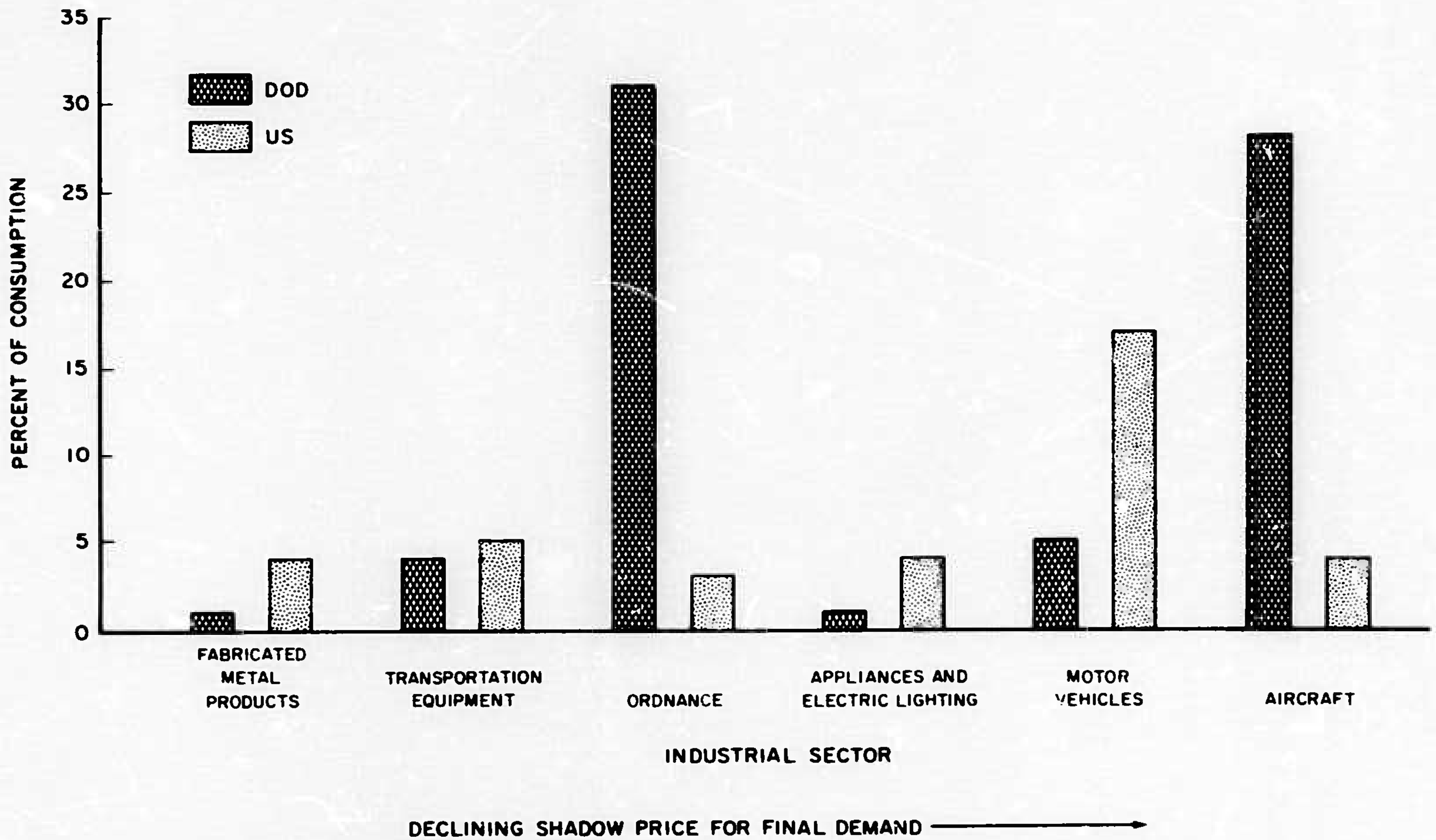

FIGURE II-6. DOD AND U.S. ALUMINUM USE THROUGH CONSUMPTION OF PRODUCTS WITH HIGH FINAL DEMAND SHADOW PRICES DURING A SHORTAGE OF ALUMINUM

framework is that DoD is likely to experience supply problems for ammunition products during an aluminum shortage. Indicators of other potential DoD supply problems can be derived for 17 material and energy resources from information presented in the report and the appendix to the report.

- Additional extensions of the resource shortage model are recommended to explicitly treat substitution and price effects that occur during shortages.

III DOD MATERIAL CONSUMPTION REQUIREMENTS

A. Introduction

The purpose of the analysis and results presented in this section is to estimate the amount of each of 17 critical materials consumed by U.S. industries in order to supply DoD final demand. The methodology by which these estimates were derived is discussed first, followed by presentation of the results.

B. Methodology of Estimation of DoD Material Consumption

The methodology was based on the use of national input-output tables of industry purchases and sales supplemented with data on the consumption of each material by industry. Since the mathematics of manipulation of input-output tables is complex and frequently distracts from the physical meaning of the interactions, the methodology is explained in two parallel parts: (1) a conceptual description of the processes represented by the calculations and (2) the mathematical formulation involved. Thereafter the implementation of the calculations is discussed.

1. A Conceptual Description of the Methodology

The goods and services that the DoD purchases from U.S. industries require the consumption of specific materials for their manufacture and provision. The nature of this consumption is of two types:

- Direct consumption--the material that an industry uses to manufacture the product it sells to DoD
- Indirect consumption--the material consumed by a given industry to manufacture products that are sold to other industries for input to the manufacture of products that are in turn sold to DoD.

Both types of consumption are necessary to supply DoD. Thus, the material required to produce the goods and services purchased by DoD is the sum of the direct and indirect consumption.

A useful way of describing the material consumption of an industry is illustrated in Figure III-1.

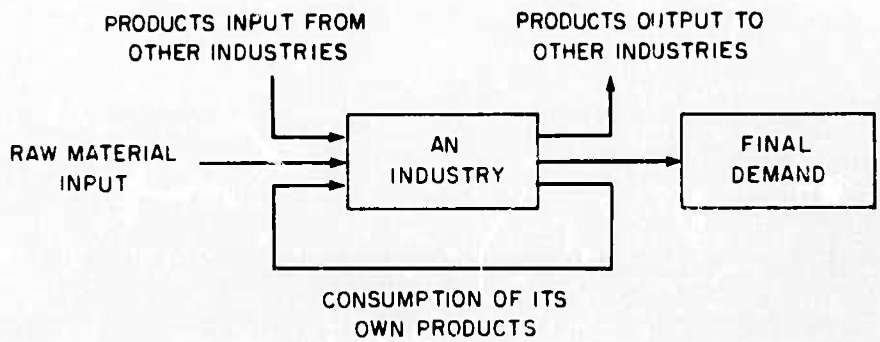

FIGURE III-1. REPRESENTATION OF MATERIAL CONSUMPTION REQUIREMENTS OF AN INDUSTRY AND ITS FINAL DEMAND

As shown in this figure, material is first transferred to an industry from the material source industry. This source is a processing, refining, or fabricating industry. The receiving industry consumes the raw material in the manufacture of its products. These manufactured products are then distributed to one or more of three outlets: the ultimate consumer, other industries that require them as inputs to manufacture their own products, and itself. These three outlets are referred to as final demand, intermediate demand, and self-consumption, respectively.

For the system illustrated in Figure III-1, the total material required as inputs to an industry is equal to that required for the outputs. The inputs include the raw material plus the material required for the products input from other industries. The outputs include the material required to produce the output to final demand plus the material required to produce the output to other industries. This description of the flow of material in an industry applies to all industries. Since

the industry flows are each individually balanced (i.e., materials input equals materials output), the description in Figure III-1 of material flow into and out of an industry may be generalized to describe the total flow of materials throughout the economy that are required to produce the set of specified final demands.

The previous definition of direct and indirect consumption can be understood by referring to Figure III-1. The direct consumption is that portion of the raw material input consumed to manufacture the products output directly to final demand. All other consumption is indirect. Thus, direct consumption is that which goes from raw material to final demand products without any intermediate consumption of the product. Indirect consumption involves intermediate products that are consumed to produce final demand.

2. Mathematical Formulation

The estimates of material consumption are based on the input-output tables of interindustry and final demand transactions that describe the U.S. economy for a particular year. Three different forms of input-output tables are available. The first is the transactions table, in which the dollar sales of an industry to all other industries and to final demand are shown. The second form is the direct coefficients table, represented by the matrix A, which is formed by dividing each transaction by the total sales of the industry making the purchase. The direct coefficients are related to the final demand by:

$$(I - A) \cdot X = Y \qquad \text{equation (1)}$$

where I = the identity matrix, X = vector of gross outputs on total sales, and Y = vector of final demands. This relationship can be inverted as:

$$(I - A)^{-1} \cdot Y = X \qquad \text{equation (2)}$$

where $(I - A)^{-1}$ = the total requirements coefficients matrix and is formed by inverting the (I - A) matrix. This total requirements coefficients matrix is the third form of the input-output tables.

The vectors X and Y and the matrix $(I - A)^{-1}$ can be understood in terms of the direct and indirect flows, as discussed previously. The final demand vector, Y, contains dollar flows to industries from final demand. It is thus representative of the direct dollar flows from final demand to industries for the purchase of industrial products. Materials that the industry uses to produce these products constitute the direct materials flow from that industry to final demand, as defined previously. The total requirements matrix, $(I - A)^{-1}$, may be thought of as a transformation that operates on the final demand vector to yield the gross output vector, X. The gross output vector contains the total dollar flows to industries from both the consumer (final demand), the other industrial sectors (intermediate demand), and itself (self-consumption). The materials that the industry uses to manufacture the products for final and intermediate demand and self-consumption constitute the direct and indirect materials flow from the industry.

Since the total requirements coefficients matrix, $(I - A)^{-1}$, and the final demand vector, Y, are available, equation (2) provides a method of calculating the gross output vector, X. The total material consumption, direct and indirect, to fulfill final demand can then be calculated directly for the gross output vector. The formulation of the material consumption estimate is expressed in its most general form by:

$$M \cdot X = C \qquad \text{equation (3)}$$

where M = the row vector whose elements are the ratio of material consumed by each industry to the gross output or sales of that industry, expressed as weight of material per dollar of gross output, and C = the total amount of material consumed to fulfill final demand, a scalar quantity.

Substituting equation (3) into equation (2) gives:

$$M \cdot (I - A)^{-1} \cdot Y = C \qquad \text{equation (4)}$$

This equation is the basic relationship used for the material flow calculations in this study. The identification of specific direct and indirect material flows is derived from the dissection of equation (4) and the interpretation of the component terms of that expression.

The quantitative estimate of the total direct and indirect material consumption required to produce the final demand for the products of each industry can be derived from the relationships of equation (4).

Let m_i = the quantity of material consumed by industry i per dollar of output or sales of that industry. This is the material consumption ratio, i.e., the element of row vector M.

r_{ij} = the dollars of sales or output from industry i to industry j to supply $1 of sales of product j to final demand (product j is that which is produced by industry j). This is the element of the total requirements coefficient matrix $(I - A)^{-1}$.

f_j = the dollars of sales by industry j to final demand. This is an element of the final demand vector, Y. Since we are interested in estimating material consumption required to fulfill DoD final demand, we define the term f_j = the dollars of sales by industry j to DoD final demand. Then f_j is an element of the DoD final demand vector, designated Y.*

Using these defined quantities, a single product factor or equation (4) is $m_i \cdot r_{ij} \cdot f_j$ = quantity of material required by industry i to support the sales of product j to DoD. The basis for interpretation of this product can be seen by noting the units as follows:

---

*A basic assumption of the input-output formulation is that the output of each industry is directly proportional to the inputs. That is, if each input is doubled, the output is also doubled. This proportionality between inputs and outputs allows the use of the same coefficients of the table to calculate the output required to fulfill any bill of final demand requirements. Thus, the same formulation is used in this study for calculating both the material requirements for DoD final demand and the total U.S. final demand. We generally use f_j and Y_j to refer to either DoD or total U.S. final demand, as the distinction between the two is clear from the context of the discussion.

$$\underset{m_i}{\left[\frac{\text{Quantity of material}}{\text{\$ sales of industry i}}\right]}\ \underset{r_{ij}}{\left[\frac{\text{\$ sales of industry i}}{\text{\$ sales of product j to final demand}}\right]}\ \underset{f_j}{\left[\text{\$ sales of product j to DoD final demand}\right]}$$

= quantity of material required by industry i to provide sales of project j to DoD final demand.

This product, summed over i and j (i.e., summed over all industries and all final demands), equals the total material required, C, both direct and indirect, to produce the final demand.

The individual components of material consumption of an industry, k, as in Figure III-1 are obtained by considering the partial summations as follows:

$$\sum_i m_i \cdot r_{ik} \cdot f_k = m_k \cdot f_k + m_k \cdot (r_{kk}-1) \cdot f_k + \sum_{i \neq k} m_i \cdot r_{ik} \cdot f_k \quad \text{(equation 5)}$$

The terms of this equation can be identified with corresponding portions of Figure III-1 as follows:

> total material required to fulfill final demand for product k = material used for products sold to final demand k + material used for products for self-consumption + material used by other industries to supply products to industry k.

A second partial sum of interest is:

$$\sum_j m_k \cdot r_{kj} \cdot f_j = m_k \cdot f_k + m_k \cdot (r_{kk}-1) \cdot f_k + \sum_{j \neq k} m_k \cdot r_{kj} \cdot f_j \quad \text{(equation 6)}$$

Equation (6) is interpreted as follows:

> total material input into industry k to manufacture its products = material used for products sold to final demand k + material used for products for self-consumption + material used for products supplied to other industries.

Summing the left-hand side of equation (5) over all final demands gives the total direct and indirect materials consumption to fulfill demand for product k, as does summing the left-hand side of equation (6) over all industries. Although not so obvious, it is easy to show that the terms representing the inputs in equations (5) and (6) sum

to the same quantity as the terms representing outputs for each industry final demand pair [i.e., for the same k in equations (5) and (6)].*

3. Data Inputs and Implementation

Four types of data were used to develop the material consumption estimates. These are an interindustry input-output table, U.S. and DoD final demand estimates, deflation factors to transform all dollar inputs into constant dollars, and material consumption estimates for each industry. The manner in which these inputs were combined is shown in Figure III-2.

a. Interindustry Input-Output Table

The basic input-output table used was the 367-sector table for 1967, published by the Bureau of Economic Analysis, U.S. Department of Commerce.[1†] This is the latest complete table of industry transactions published by the U.S. government. Although tables for as late as 1972 have been derived by others by extrapolation techniques, the Department of Commerce tables are the most widely used because they are based on the most complete data. Therefore, the 1967 table was used as the basis for this study.

As shown in Figure III-2, we used an input-output table consisting of 404 sectors. This input-output table was derived from the Bureau of Economic Analysis 367-sector input-output table by disaggregating the mining industries from 5 to 44 sectors. The disaggregation was done by the Lawrence Berkeley Laboratory from data supplied by the U.S. Bureau of Mines. The 404-sector table was then aggregated to 150 sectors to correspond

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*References are listed at the end of the report.

†To do this, note that the direct input and output terms are identical, as are the self terms. It remains to show that

$$\sum_j m_k \cdot r_{kj} \cdot f_j + \sum_{i \neq k} m_i r_{ik} \cdot f_k = \sum_i m_i r_{ij} \cdot f_k + \sum_{j \neq k} m_k \cdot r_{kj} \cdot f_j$$

but note that

$$\sum_j m_k \cdot r_{kj} \cdot f_j = \sum_{j \neq k} m_j \cdot r_{jk} \cdot f_k + m_k r_{kk} \cdot f_k$$

and

$$\sum_i m_i \cdot r_{ik} \cdot f_k = \sum_{i \neq k} m_i \cdot r_{ik} \cdot f_k + m_k r_{kk} \cdot f_k.$$

If the last two expressions are substituted into the first, the terms on each side of the equation match up exactly.

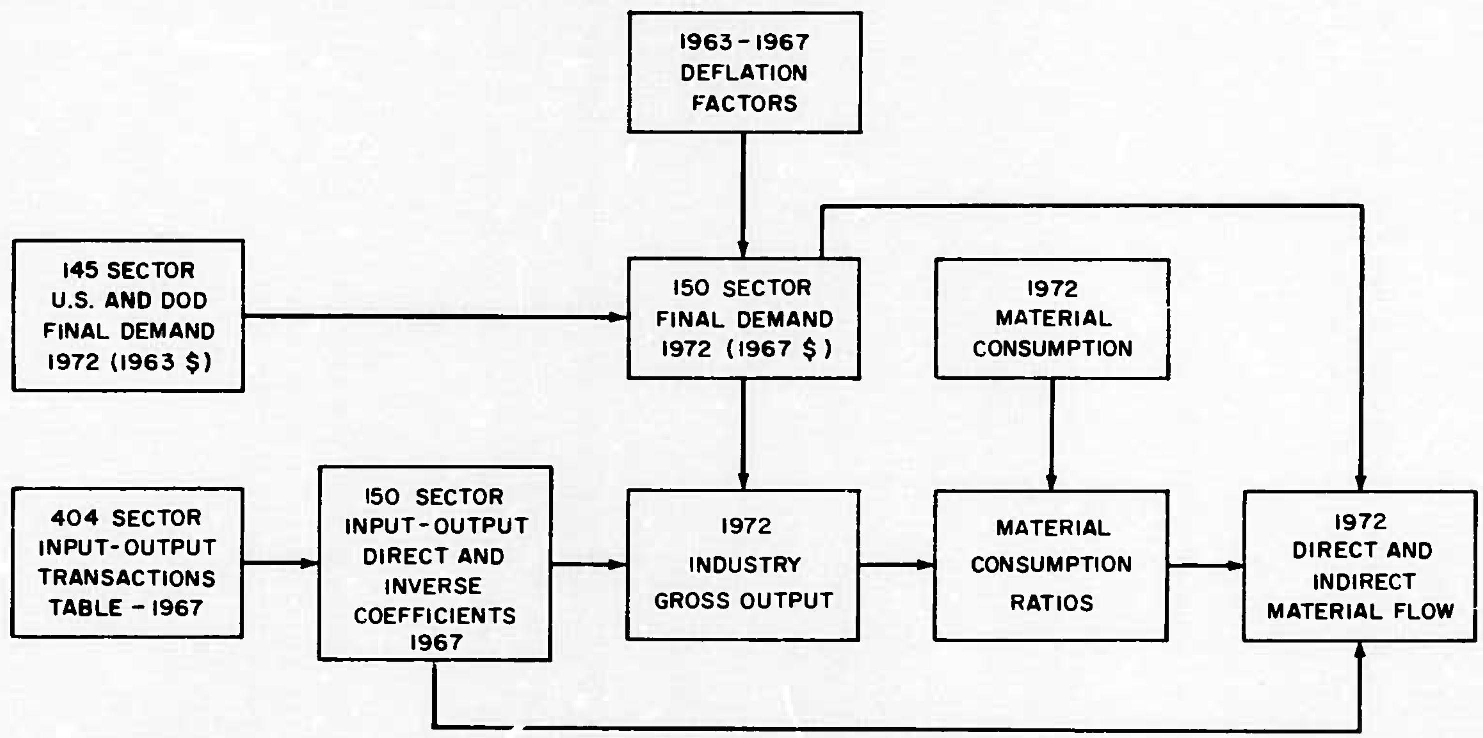

FIGURE III-2. BLOCK DIAGRAM OF THE MAJOR STEPS OF THE CALCULATION OF MATERIAL FLOW

with the level of aggregation of the final demand estimates used. The definition of each of the 150 sectors is given in the appendix to this report.

b. Final Demand

The estimates of both U.S. and DoD final demand for 1972 were assembled by Mr. Albert Schulman, Federal Preparedness Agency, General Services Administration.[2] The DoD final demand was derived from information published by the office of the Assistant Secretary of Defense (Comptroller) in the "Monthly Report on Status of Funds by Functional Title." The U.S. final demand is from Department of Commerce data. These estimates were furnished at an aggregation level of 145 sectors. Five energy sectors were further disaggregated by partitioning the final demand figures for those sectors in proportion to the more detailed 1967 final demand of the input-output table. The estimates, furnished in 1963 dollars, are shown in the appendix to this report inflated to 1967 dollars to match the input-output table.

c. Deflation Factors

The intermediate and final demand purchases were converted into constant 1967 dollars, using deflation factors assembled by Lawrence Berkeley Laboratory from data published by the U.S. Bureau of Labor Statistics. The choice of 1967 dollars was made to establish consistency between the consumption ratios, the final demand vectors, and the input-output coefficients. Since the end result of the calculation, amount of material to fulfill final demand, is expressed in units independent of dollars, the result is not affected by the year chosen for the constant dollars. The deflation factors are shown in the appendix.

d. Material Consumption Estimates

The final data input required was the amount of material consumed by each of the 150 sectors. The most detailed listing of industry consumption available is that developed by Dr. Herman Director, of Herman Director Associates, for the Federal Preparedness Agency.[3] These

consumption estimates, which were at a four-digit SIC code level, were aggregated to the 150-sector level for this study. The 13 materials for which consumption estimates were obtained from this source are:

Aluminum	Platinum	Tungsten
Cobalt	Silver	Zinc castings
Copper	Tin	Zinc galvanizing
Lead	Titanium metal	
Nickel	Titanium pigment	

Industry consumption estimates for three energy resources petroleum, natural gas, and coal--were obtained as follows. Coal consumption data were published by the U.S. Bureau of Census[4] for 1971 at a four-digit SIC code level. Petroleum and gas consumption data for 1968 were obtained from the 1968 Minerals Yearbook[5] at a two-digit SIC code level; these data were disaggregated to 150 sectors according to the proportion of 1967 sales to each sector of the petroleum refining industry and gas utilities, respectively. These consumption figures were scaled to 1972 using the total consumption for each listed in the 1972 Minerals Yearbook.

Finally, U.S. industry consumption of chromium was added to the list because of the strategic importance of this material. The data used for this material were obtained from the 1972 Minerals Facts and Figures, published by the U.S. Bureau of Mines at a two-digit SIC code level.[6] Only the 83 percent of domestic consumption allocated to specified industries was included. The 17 percent of consumption allocated to the general title "other industries" was not considered. The consumption figures were disaggregated to the 150-sector level by partitioning in proportion to sector gross output.

The particular definition of material consumption used in these estimates should be noted. The material flow cycle goes from mining, through processing, to use in manufacture, and finally to sales as products. The point in that cycle at which consumption is measured is, in general, that point at which the material loses its separate identity and becomes combined with other materials in the manufacturing process. This point, for most materials, is the purchase by a manufacturing industry of the material in the form of ingots, plate, or other fabricated products from the metal refining or fabricating industries. Thus, the industries counted

as "consuming" materials are those that convert the material into final products, rather than either mining or intermediate refining and fabricating industries. This choice of a particular point in the flow at which to register material consumption is necessary to avoid multiple counting of the consumption of the same material.

As a result of counting consumption only at the input to manufacturing industry, material sold by the mining or processing industries directly to final demand is not included in the material flow calculations. Thus, for example, aluminum purchased from the aluminum fabricating industries by DoD, the household sectors, or for export is not included in the consumption estimates. Actually, very little of the metal resources is sold directly to final demand, except that which is exported. Thus, the U.S. and DoD consumption figures for these resources adequately represent the complete domestic consumption. However, it should be borne in mind that large fractions of the domestic consumption of some of these metals are exported in addition. The metals whose exports are greater than 1 percent of the domestic consumption are shown in Table III-1.

Table III-1

EXPORT OF METAL RESOURCES AS A PERCENTAGE OF DOMESTIC CONSUMPTION

(1972)

Metal	Exports as a Percentage of Domestic Consumption
Platinum	52%
Titanium metal	27
Silver	20
Nickel	10
Chromium	6
Aluminum	5

The energy resources, however, are sold in significant quantities directly to domestic final demand. Specifically, 43 percent of the petroleum, 24 percent of the natural gas, and 12 percent of the coal

consumed domestically is sold directly from the resource processing industries to final demand. Thus, the energy consumption estimates refer only to those Btus that are consumed by industry to manufacture their products sold to final demand. The energy consumed directly by the household or transportation sectors of final demand is not included.

e. Key Assumptions

The most critical assumptions behind these estimates of industry transactions at the national level are those that relate to the input-output methodology. In using the direct and total requirements coefficients to calculate the gross output of each industry to satisfy only part of the total U.S. final demand, namely that of DoD, we assumed that the output of each industry is directly proportional to the input of that industry. Thus, if DoD final demand for a particular industry product is 20 percent of the national final demand for the product, we have assumed that 20 percent of the resources are required to fulfill it. Since DoD final demand requirements are actually a portion of national requirements, and are not produced separately, it is not unreasonable to approximate the incremental input required to produce DoD final demand as the same proportion of that required to supply the national final demand.

A more significant assumption of these calculations is that the output of each industry is homogeneous. That is, there is no differentiation between the products sold by an industry to other industries or to final demand. Each sale transaction of an industry is treated as if it were exactly the same product being sold to DoD. While this assumption is acceptable for many of the products comprising DoD final demand, it is clearly unrealistic in the case of such specialized goods as aircraft and electronics. In order to treat the product differences between DoD and U.S. final demand, each industry sector involved would have to be disaggregrated into two parts, one producing for DoD and the other producing for the rest of the United States. Such a disaggregation would require the differentiation of the inputs to each sector involved and would require considerable data gathering to produce a credible degree of accuracy. Less rigorous estimates could be used, however, to

give an indication of the effects. Such estimates were not developed for this study. To the extent that most DoD purchases of products from a given industry are similar to the remaining outputs of that industry, the approximation made is valid. We believe this to be generally the case.*

Another assumption was that the coefficients of the 1967 input-output table have not changed significantly between 1967 and 1972; that is, the manufacturing technology represented by the dollar amount and distribution of inputs required to produce a dollar of output has not changed to a major degree during this time period. This is also a reasonable assumption for nearly all industries. However, a few, such as the computing equipment industry, have shown major changes during this time period. Analysis of the effects of these changes on the material consumption estimates was not made, but it is expected that the effects of this assumption are small.

f. Implementation

The flow diagram in Figure III-2 summarizes the method of calculating direct and indirect material flows. The 404-sector input-output table was aggregated to 150 sectors. The 150-sector table was transformed into a table of direct coefficients by dividing each transaction by the gross output of the purchasing industry. The total requirements coefficients needed for the material consumption calculations were then obtained by inverting the matrix of direct coefficients. The final demand estimates were deflated and disaggregated to 150 sectors in 1967 dollars to match the input-output table. The final demand and total requirements coefficients were then combined, as shown previously in equation (5), to give the gross output for each sector. The material consumption for each sector was then divided by the gross output to give the material consumption ratios. Finally, the three factors--final demand, total requirements coefficients, and material consumption ratios--were multiplied and added as shown in equations (3) and (4) to produce the direct and indirect material consumption estimates for each sector.

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*In fact, most of the specialized products required by DoD are purchased from industries that supply most of their output to DoD (e.g., ammunition and missiles).

C. Results

The results of the calculations described are voluminous, containing a detailed data base useful for studies requiring an analysis of interindustry flow of materials. For each of the 17 materials, computer printouts are available showing the components of material consumption for each of 150 sectors. An example of the computer printout of these data is given in the appendix. In addition, a detailed breakdown of the indirect industry consumption of each of the component industries comprising the consumption in Figure III-1, labeled "products input from other industries" and "products output to other industries," is possible at very little additional cost by using existing computer programs.

Without selective condensation and illustrative presentation, such data, while useful as input to other studies, provide very little understanding of the important relationships involved in interindustry flow of materials. The difficulty posed by condensation is the danger of overlooking key underlying relationships by indiscriminate aggregation. Thus, considerable effort was devoted in this study to developing ways of presenting the data that are both comprehensible and illuminating and that maximize the likelihood of identifying the important characteristics of the estimates. Two forms of visual presentation were developed: a computerized flow diagram and a consumption circle diagram.

This part of the report deals with these two forms of presentation. To maintain a continuity of presentation and to allow the reader to develop insight into the power of the approach and methodology, two materials are used as examples: aluminum and petroleum. Corresponding presentations for all materials are included in the appendix. The analysis of these two materials does not attempt to be comprehensive, but will be illustrative of the type of information that can be derived from material flow calculations. Summary tables of key characteristics of all the materials are also presented and discussed.

1. Material Flow Diagrams

Figure III-3 is the material flow diagram developed for U.S. domestic consumption of aluminum. The detailed consumption inputs and

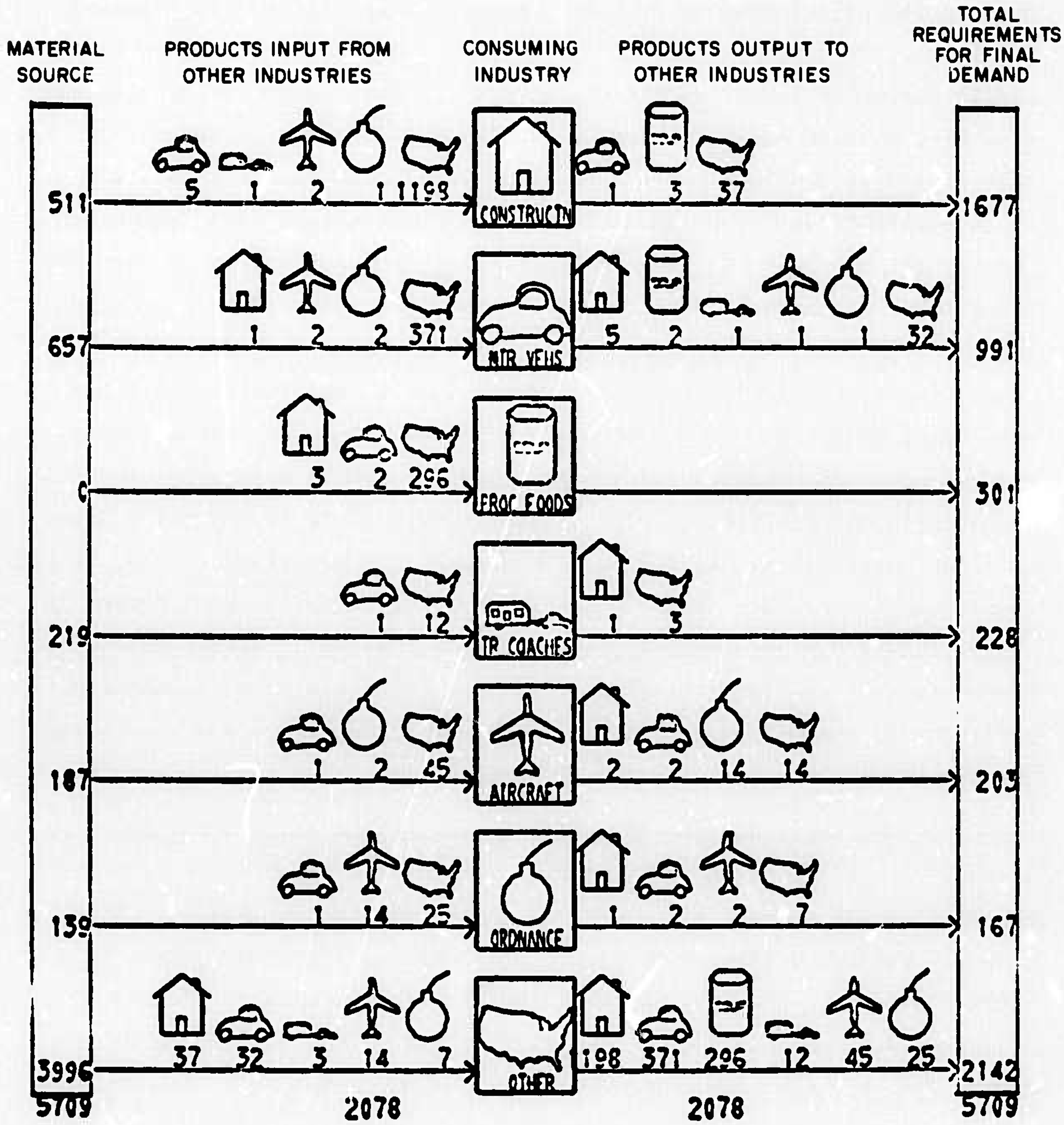

FIGURE III-3. 1972 ALUMINUM CONSUMPTION BY THE U.S.
(Thousonds Short Tons)

outputs of the six industries that required the most direct and indirect consumption of aluminum to provide their products sold to final demand are shown. The requirements of all other industries are assigned to a single composite industry labeled "other." Where several industries each have high final demand consumption requirements and are closely associated, they have been combined under a single label. Examples of this are the construction industry, which includes "new construction" and "maintenance and repair construction," and the motor vehicle industry, which includes "truck and bus bodies and tractor trailers," as well as "motor vehicles and parts." Symbols representing each industry have been developed and used. The symbol identification is given in the center square labeled "consuming industry." The components of consumption for each industry correspond to those discussed previously and shown in Figure III-1. Thus, the quantity on the left labeled "material source" is that labeled "raw material input" in Figure III-1. The quantity on the right labeled "total requirements for final demand" is that arrow pointing to final demand in Figure III-1. The other labels are self-explanatory. Neither the self-consumption of the industries' own products nor the direct consumption are shown in the diagram since they both have equal input and output and are intraindustry rather than interindustry flow.

The total direct and indirect consumption of aluminum is 5,709,000 tons and is shown in Figure III-3 as the total input from the material source industries as well as the total requirements for final demand. The two totals of the input products and output products, both 2,078,000 tons, represent the total indirect consumption of aluminum excluding self-consumption, which, in this case, is 1,493,000 tons. The direct consumption, also not shown, is 2,138,000 tons.

The diagram shows that each product input is matched by a corresponding product output. Thus, the 5000 tons of aluminum in products input from the motor vehicle industry to the construction industry (shown by the auto symbol at the upper left) are matched by the same 5000 tons consumption for output from the motor vehicle industry to the construction industry (shown by the house symbol at the right of the motor vehicle industry center square). Further, the sum of the inputs of each industry

(i.e., the material source plus products input from other industries) is equal to the sum of the outputs of each industry (i.e., products output plus the total requirements for final demand). In some cases these totals do not add because of rounding.

A wealth of information can be extracted from this flow chart. A few examples of the kinds of information contained in Figure III-3 include:

1. The construction industry is the single largest user of aluminum when indirect as well as direct use is included. However, while that industry's sales to final demand require 29 percent of the total consumption of aluminum (1677/5709), only 9 percent (511/5709) of the total aluminum is consumed directly by that industry. Thus, the importance of aluminum to the construction industry is much greater than is indicated by the amount of that material it purchases from the aluminum fabricating industries.

2. Although the processed foods industry does not purchase aluminum directly, it purchases manufactured products requiring aluminum in large quantities from many industries (not shown in the flow diagram). The detailed computer printout indicates that most of this consumption for input products, 235,000 tons, is from the metal container industry, as expected. This indirect requirement of aluminum makes the processed foods industry the third largest user of aluminum even though it purchases no aluminum directly.

3. The trailer coach industry, whose primary product is mobile homes, is the fourth largest direct and indirect consumer of aluminum. Nearly all of its consumption is direct; that is, very little of the total consumption of 228,000 tons was provided by products input from other industries, and very little of the 219,000 tons of aluminum it purchased was used to make products output to other industries. Thus, either there must be a very large self-consumption of aluminum or a very large direct consumption. In nearly all

cases, self-consumption is much less than the direct consumption. Thus, the trailer coach industry is an example of a large direct user of aluminum in distinction from the processed foods industry, which is a large indirect user.

Rather than discuss this flow diagram further, let us look at the corresponding flow diagram for DoD requirements for aluminum. That diagram is shown as Figure III-4. The units have been changed from thousands of tons to hundreds of tons in order to maintain the same number of significant figures in the total consumption. Observations from this flow chart include:

1. Industries important for DoD final demand requirements are, in many cases, the same as those for the United States. Key exceptions to this are the processed foods and trailer coach industries, which were important for the United States but are replaced by the communication equipment and shipbuilding industries for DoD. However, the ranking of the common industries has changed. The construction and motor vehicle industries are less extensive consumers of aluminum for DoD than they are for the entire nation.

2. The ordnance industry, as expected, is the largest direct and indirect user of aluminum for DoD final demand. A major indirect input comes from the aircraft industry, 8900 tons of aluminum consumption, which, as shown in the detailed computer output, is primarily for aircraft parts for guided missiles. Actually, the guided missile industry is physically a part of the aircraft industry, but the input-output tables treated them as separate industries. The aircraft industry is also the major indirect output from the ordnance industry. This output is primarily ammunition.

3. Although the new construction industry has significant purchases of aluminum from the aluminum fabricating industries, it is shown as selling no products to other industries. The input-output tables show new construction as capital

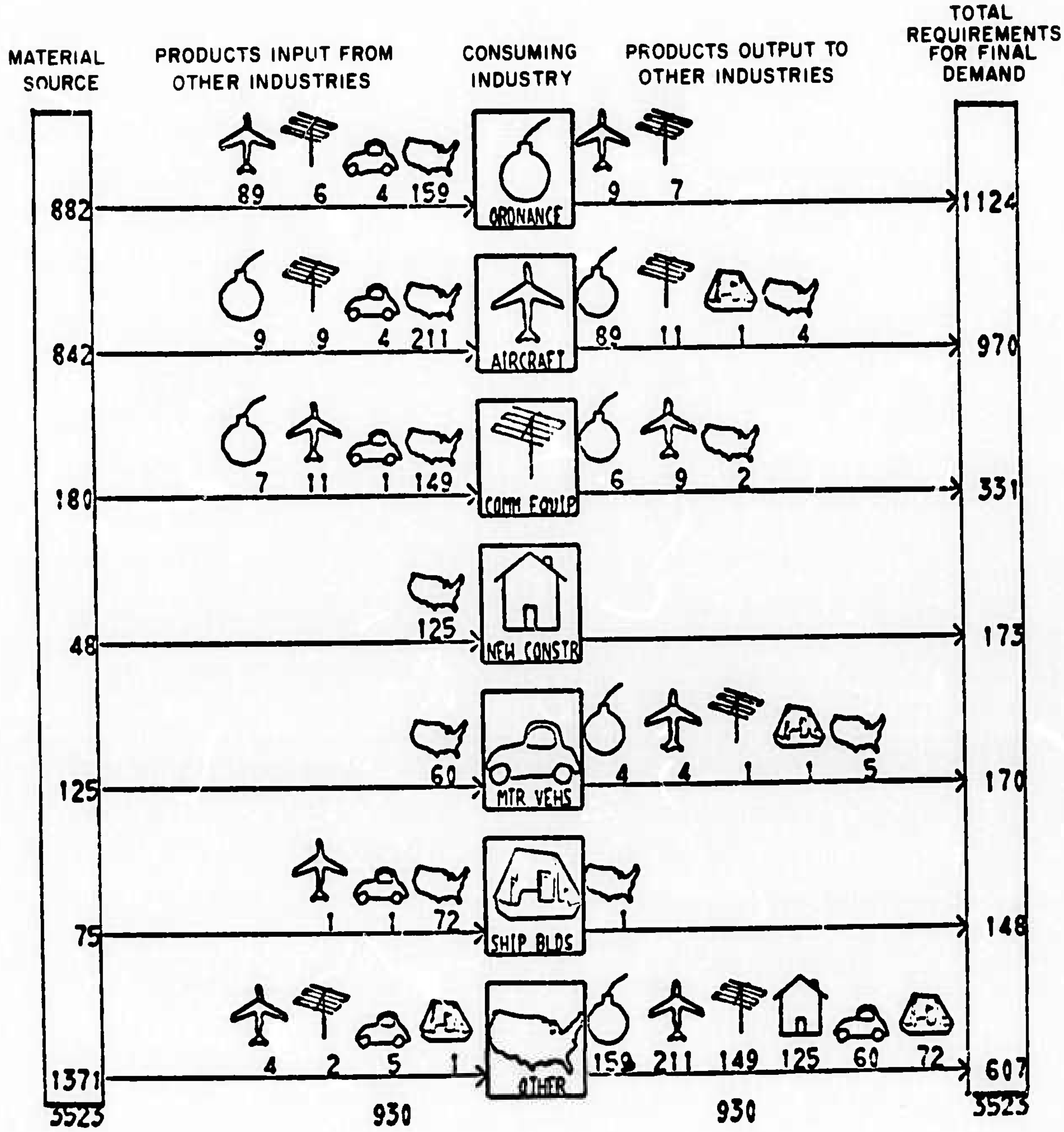

FIGURE III-4 1972 ALUMINUM CONSUMPTION BY THE DOD
(Hundred Short Tons)

investment for industry, which is a sector of final demand. Thus, although the new construction industry is shown as receiving many products from other industries, it has no product that it sells to industry in return. It sells only to final demand. This example illustrates the importance of recognizing the specific conventions of the input-output tables when interpreting these estimates. Thus, the main purpose of these figures is to raise questions and stimulate speculation that must be pursued further before firm conclusions can be drawn.

The other example to be discussed is that of petroleum. Figures III-5 and III-6 show the flow diagrams for U.S. and DoD consumption of petroleum, respectively. Looking at the U.S. consumption first (Figure III-5), we can make some key observations.

1. The new construction final demand has the greatest requirements of all final demand sectors for petroleum. Almost all of this requirement (nearly 90 percent) is indirect, of which a large portion, 490 trillion Btus, comes from the motor freight transportation industry. This consumption represents the oil and gas used by the motor freight industry to transport building materials. The largest indirect input of petroleum to the construction industry from the "other" industries category is from the paving and asphalt industry, as expected. This high level of dependence of the new construction industry on petroleum has not been generally recognized; it is one of the findings that illustrate the usefulness of this methodology.

2. The petroleum refining industry is both the source industry for the consumption shown here as well as a key consuming industry. The explanation for this is straightforward. The petroleum refining industry consumes much of its own products as fuel. Thus, the consumption associated with the outputs of the petroleum refining industry to other industries represents the fuel consumed by the petroleum

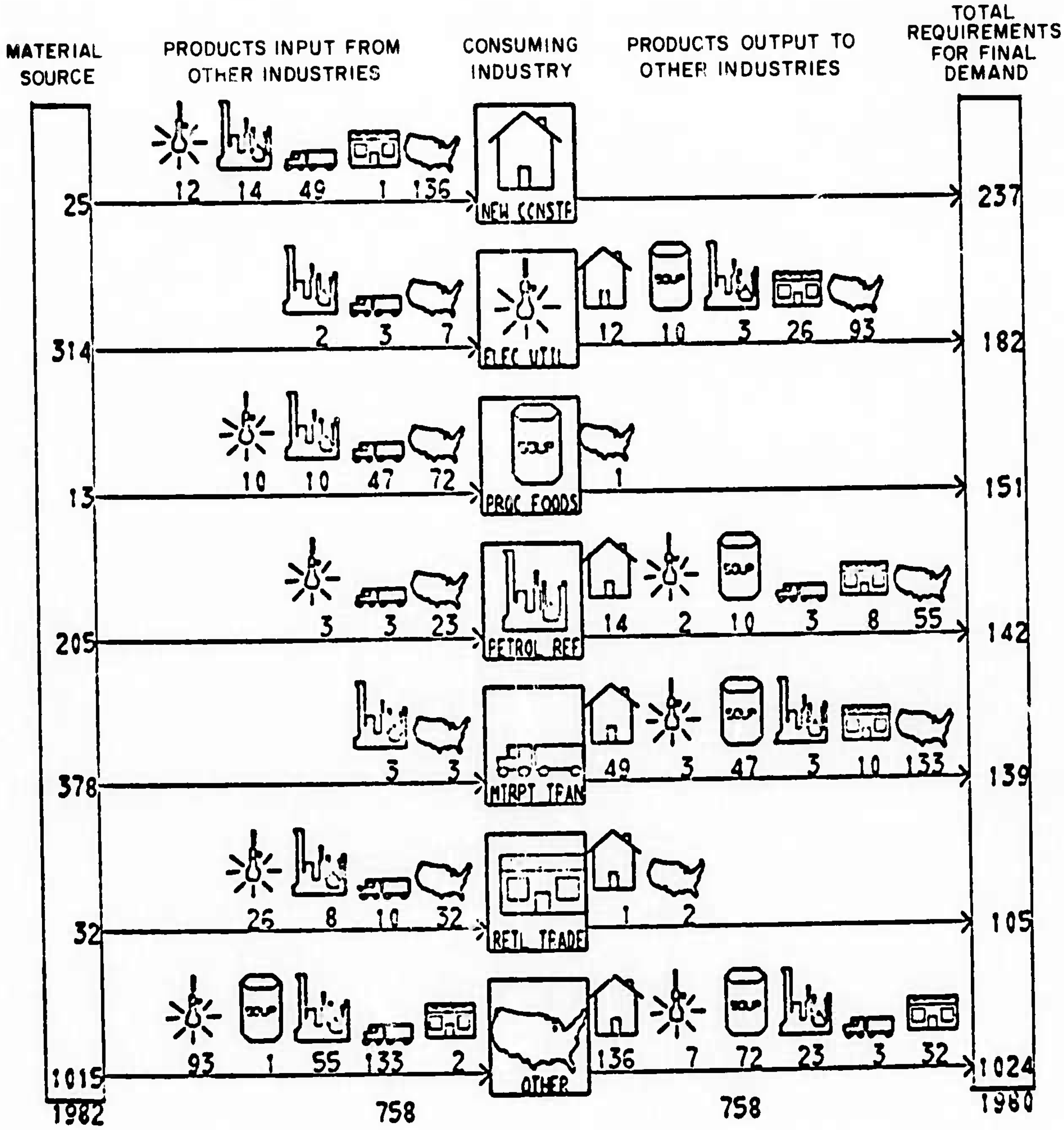

FIGURE III-5. 1972 PETROLEUM CONSUMPTION BY THE US.
(Ten Trillion Btu)

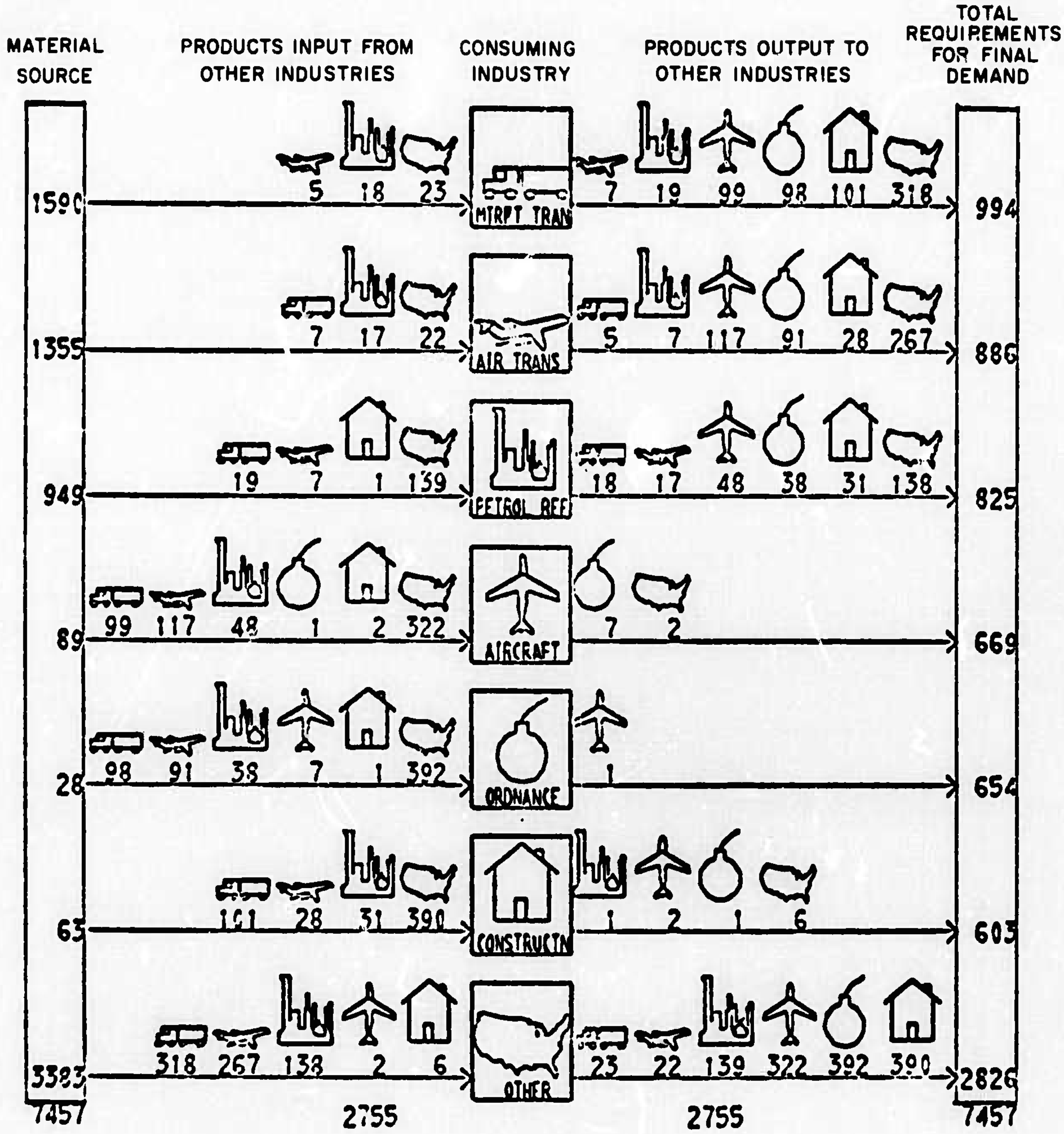

FIGURE III-6. 1972 PETROLEUM CONSUMPTION BY THE DOD
(Hundred Billion Btu)

refining industry to furnish the petroleum products to other industries. This self-consumption portion of the indirect flow was not seen with the aluminum example. Actually, the primary aluminum industry consumes about 5 percent of its own products, and the aluminum rolling and drawing industry consumes about 3 percent of its own products, according to the input-output tables. Dr. Director, in designating consumption of mill products and castings for the metal resources, did not count the self-consumption of the metal fabricating industries but counted only the material input to the product manufacturing industries. The allocation of the energy resource consumption used in this study was done by the U.S. Bureau of Mines and did include the self-consumption of the material refining industries. The self-consumption is less than 10 percent and is generally 2-5 percent for the materials considered in this study; it is therefore not an overriding factor in the results shown. Nevertheless, it is clearly important enough to be included, as the petroleum example indicates.

3. The construction, processed foods, and trade industries are similar in their petroleum requirements in that they each have very small direct input requirements but large indirect input requirements for petroleum. They also each sell nearly all of their products directly to final demand. The electric utilities, petroleum refining, and motor freight transportation industries are examples of the other type. These latter industries consume large amounts of petroleum directly from the petroleum refining sector and use a major share of this consumption to furnish products to other industries. Relatively little petroleum consumption is required to furnish their inputs from other industries, however.

Turning finally to the flow diagram for DoD consumption of petroleum, shown as Figure III-6, we find no surprises. The top final demands for the U.S. consumption of petroleum are still important to DoD but are

shifted down in priority to be superseded by motor freight and air transportation. Ordnance also becomes a major petroleum consumer.

2. Consumption Circle Diagrams

The flow diagrams present a considerable amount of detail on the material flows of the top six industries. An approach that presents much less detail on more industries is the more conventional circle diagram. Figures III-7 and III-8 show these diagrams for U.S. and DoD consumption of aluminum and petroleum, respectively. The consumption shown is that presented in the flow diagrams as total requirements for final demand expressed as a percentage of total consumption. The amount of total consumption is shown below each circle. The 10 final demand sectors requiring the most direct and indirect consumption are shown if they require at least 2 percent. The sectors are ordered around the circle according to the consumption amount. The advantage of this presentation is that it gives a visual indication of the relative magnitude of total consumption required for each final demand product. Thus, in Figure III-7, the two final demands of construction and motor vehicles are seen to require almost half of total U.S. consumption of aluminum. Similarly, ordnance and aircraft account for almost two-thirds of total consumption required for DoD. Petroleum consumption, as shown in Figure III-8, appears to be more evenly spread, with no sector requiring more than 13 percent of the total.

The total consumption shown beneath the figures can be used to calculate the portion of total U.S. consumption required for DoD final demand. This is estimated to be about 6 percent (352/5709) for aluminum and 4 percent (746/19,822) for petroleum. It should be borne in mind that this percent figure for petroleum consumption refers only to industry consumption and does not include petroleum sold directly to final demand. Including figures for petroleum sold to DoD and U.S. final demand results in an estimate of 5 percent of total U.S. petroleum consumption for DoD. Finally, the relative magnitude of material consumption of specific sectors for U.S. and DoD final demand can be compared. Thus, Figure III-7 shows that while aluminum consumption for the production of aircraft for U.S. final demand requires only 4 percent of the total, consumption for DoD

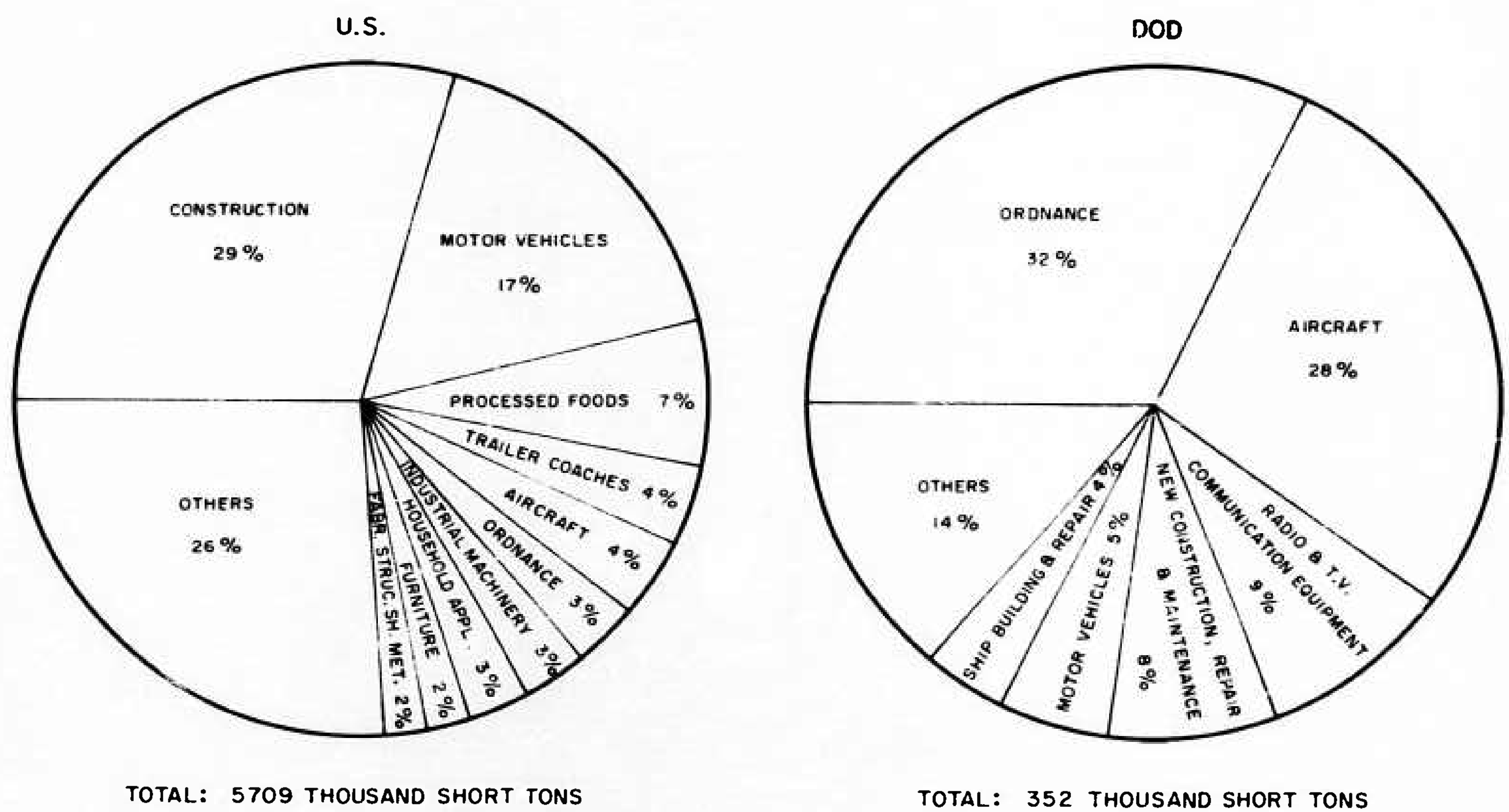

FIGURE III-7. U.S. AND DOD CONSUMPTION OF ALUMINUM BY END USE (1972)

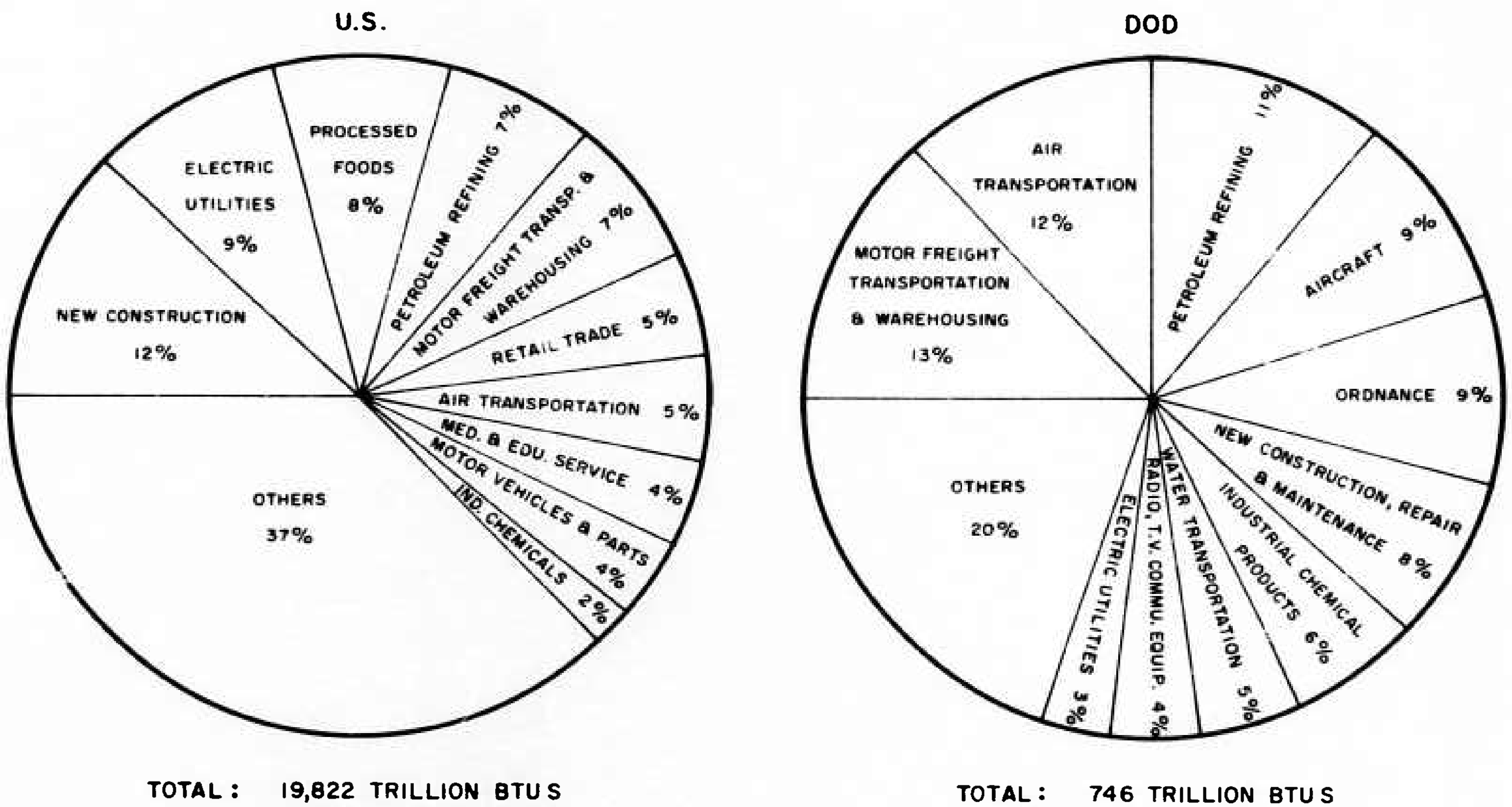

FIGURE III-8. U.S. AND DOD CONSUMPTION OF PETROLEUM BY END USE (1972)

final demand requires 28 percent of the total DoD consumption. Thus, DoD dependence on aluminum for its aircraft production is much greater than that of the United States as a whole. Similarly, the dependence of DoD on aluminum for its construction requirements is much less than that of the United States as a whole.

3. Comparisons of All 17 Materials

Many comparisons can be made of the consumption characteristics of all 17 materials from the data provided in the appendix and the additional material computed but not published. By way of a very summary illustration, Table III-2 lists two parameters measured for each material: the percentage of total consumption that is direct, and the DoD consumption as a percentage of the U.S. consumption. As explained previously, direct consumption is the amount of material that is used by an industry to produce the output sold directly to final demand. The remaining consumption is indirect, which means the amount of material used to manufacture products that are sold to another industry to be incorporated into their products before being output to final demand. Direct consumption accounts for less than half of the consumption of most materials and accounts for very little of the consumption of such materials as cobalt, tin, titanium pigment, and galvanizing zinc. Thus, Table III-2 illustrates the necessity for including indirect consumption when estimating material consumption requirements.

The last column of Table III-2, which shows DoD consumption as a percentage of U.S. consumption, includes both direct and indirect consumption.

Another set of comparisons is shown in Tables III-3 and III-4, in which the percentage of U.S. and DoD consumption of each material is shown for each sector. Only values of 1 percent or greater are shown in order to distinguish the important sectors. The letter preceding each number designates the type of consumption that is at or above 1 percent for that sector. Thus, for example, the letter "I" designates the material consumed by that industry alone to support production of all final demands. This is the consumption labeled "raw material input" in Figure III-1. The

Table III-2

CONSUMPTION PERCENTAGES FOR 17 MATERIALS
(1972)

Material	Percentage of Consumption that is Direct		DoD Consumption as a Percentage of U.S. Total
	U.S.	DoD	
Aluminum	37%	53%	6%
Chromium	31	42	5
Coal	35	18	3
Cobalt	12	11	5
Copper	42	46	5
Lead	48	64	8
Natural gas	39	32	3
Nickel	43	57	8
Petroleum	37	45	4
Platinum	31	36	4
Silver	42	31	3
Tin	4	4	4
Titanium metal	67	72	41
Titanium pigment	15	8	3
Tungsten	34	34	9
Zinc castings	68	69	4
Zinc galvanizing	22	8	4

Table III-3

PERCENTAGE OF U.S. CONSUMPTION OF 17 MATERIALS BY SECTOR

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M.TITANIUM	NMTITANIUM	TUNGSTEN	CAST.ZINC	GALV.ZINC	COAL	NAT. GAS	PETROLEUM
1 LIVESTOCK																	
2 OTHER AGRICULTURE			F 1		F 1		F 1									F 1	B 1
3 FORESTRY AND FISHERY PRODUCTS																	
4 AGRIC FOREST • FISH SERVICES																	
5 IRON • FERROALLOY ORES MINING																	
6 COPPER ORE MINING																	
7 NONFERROUS METAL ORES MINING																	
8 ANTHRACITE COAL																	
9 BITUMINOUS COAL															I 1		
10 CRUDE PETROLEUM																I 3	
11 NATURAL GAS																I 2	
12 NATURAL GAS LIQUIDS																I 4	
13 STONE • CLAY MINING • QUARRY																	
14 CHEM • FERTILIZ MINERAL MINING																	
15 NEW CONSTRUCTION	F29	F24	F12	F39	F11	F18	F13	F13	F17	F 1	F18	F 8	F 3	F19	F 9	F 9	F12
16 MAINT • REP. CONST RESID BLDG				I 1													
17 MAIN. • REPAIR CONST. ALL OTHE	I 1			B 1							F I						
18 COMPLETE GUIDED MISSLES										F A		F I		F 1			
19 TANK • TANK COMPONENTS										F 1		B I	I 2				
20 AMMUN. INC FOR SMALL ARMS	B 2		F 1	B I	I 6				F 1	F 1		B 2					
21 OTHER ORDNANCE • ACCESSORIES																	
22 ALCOHOLIC BEVERAGES	F 2								F 4		F 1				F 1	F 1	
23 PROCESSED FOODS EX ALCOHOL	F 5	F 2	F 4	F 1	F 3	F 2	F 5	F 2	F11	F 1	F 6	F 2	F 1	F 2	F 4	F 7	F 8
24 TOBACCO MANUFACTURES							F 1										
25 BROAD • NARROW FABRICS YARN																	
26 MISC TEXTILE GOODS • FLOOR COV											I 2						
27 APPAREL		F I	F 2		F 1	F 1	F 3	F 1	F 1		F 2	F 1		F I	F 2	F 2	F 2
28 MISC FABRIC TEXTILE PRODUCTS																	
29 LUMB • WOOD PROD EX CONTAINERS																	
30 WOODEN CONTAINERS																	
31 HOUSEHOLD FURNITURE	B 2		F I			F I			F 1		F 2			F 2			
32 OTHER FURNITURE AND FIXTURES	B I					F 1			F 1		F 1			A 1			
33 PULP PAPER • PAPERBD MILLS															I 2	I 2	I 1
34 PAPER PROD. EX CONTAIN • BOXES											I2I						
35 PAPERBOARD CONTAINERS • BOXES	I 1																
36 PRINTING AND PUBLISHING					B I		F 1	F 1	B 1		F I			I 1	F I	F I	F I
37 INDUS CHEM EX ALUMINA		I 6	I27		I 3	I 1	I42	I 2	I 5			I 1		I 1	I 2	I10	I10
38 FERTILIZERS • AGRIC CHEM		I I															
39 MISC CHEM PRODUCTS		I I	B I				F 1				I 2						
40 PLASTICS MATERIALS • RESINS			F I				F 1				I 8						
41 SYNTH RUBBER																	
42 CELLULOS • NONCELLULOS FIBERS															I I		
43 DRUGS			F I				F I										F I
44 CLEANING PREPARATIONS			F 1				F 2		F 1		F 1					F 1	F 1
45 TOILET PREPARATIONS			F 1				F 1		F 1		F 1						

Table III-3 (Continued)

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M. TITANIUM	N TITANIUM	TUNGSTEN	CAST. ZINC	GALV. ZINC	COAL	NAT. GAS	PETROLEUM
46 PAINTS AND ALLIED PRODUCTS					I 3						I53			I 1			
47 PETROLEUM REFINING		F 1	F 1		I19	B 1	I18		F 1		F 1				F 1	F10	I10
48 PAVING + ASPHALT MATERIALS																	I 6
49 TIRES + INNER TUBES			F 1				F 1										
50 OTHER RUBBER + MISC PLASTICS			F 1				F 1				I 4			I 6			
51 LEATH TANN + INDUST LEATH PROD																	
52 FOOTWEAR + OTHER LEATH PROD			F 1				F 1				F 1			F 1			
53 GLASS AND GLASS PRODUCTS								I 1								I 1	
54 STONE AND CLAY PRODUCTS		I15			I 2		I 5				I 3				I 2	I 3	
55 BLAST FURN + BASIC STEEL PROD	I 1		1 6						I24			I 1			I21	I 4	I 1
56 IRON + STEEL FOUNDRIES			I21			I 1											
57 IRON + STEEL FORGINGS												I 1					
58 PRIMARY IRON + STEEL PROD NEC																	
59 PRIMARY COPPER									F 1								
60 PRIMARY ZINC																	
61 PRIMARY ALUMINUM INC ALUMINA																I 1	
62 OTH PRIME NONFERR MET INC LEAD					I 2				I 3								
63 SECOND NONFERR METALS					I 5			I 8	I28								
64 COPPER ROLLING + DRAWING	I 1				I 1				I11					I 8			
65 ALUM ROLLING + DRAWING																	
66 OTH NONFERR ROLLING + DRAWING									I 2			I11		I 1			
67 NONFERR WIRE DRAW + INSULATING	I 7			I23	I 3												
68 ALUM CASTINGS														I 4			
69 BRASS BRONZE + COPPER CASTINGS	I 1													I 1			
70 NONFERR CASTINGS NEC	I 1		I12		I 2									I25			
71 NONFERR FORGINGS																	
72 METAL CONTAINERS	I10								I20								
73 HEAT + PLUMB PROD EX ELECTRIC	I 1	I 2		I 2		I 7											
74 FAB STRUC SHEET + OTH MET PROD	I16	I12		I 2		I10			F 1					I 5			
75 SCREW MACHINE PRODUCTS		I 3		I 4		I 2											
76 METAL STAMP INC AUTOMOBILES	I 5	I 9		I 2		I 5			B 1					I 1			
77 OTHER FABRICATED METAL PROD	I 7	I 7	I24	I 5	I 2	I 8		I 8	I 4			I 5	I 4	I23			
78 ENGINES + TURBINES	B 1	B 1	F 1	B 1		B 1			F 1	F 1		B 2		F 1			
79 FARM MACHINERY	F 1	B 2	F 2	F 1		B 1			F 1			F 2	B 1	F 2	F 1		
80 CONSTR MIN + OILFIELD MACHINRY	F 1	B 2	F 2	B 1		B 3			F 1			B 5	B 2	F 1	F 1		
81 MATERIALS HANDL MACHIN + EQUIP		B 1	F 1									F 1		F 1			
82 METALWORK MACHIN + EQUIP		I 3	I 9	F 1		I 2			F 1			I49		F 1			
83 SPECIAL INDUS MACHIN + EQUIP	B 1	B 2	F 1	F 1		I 8			F 1	I16		F 2		F 1			
84 PUMPS + COMPRESSORS		B 1	F 1			I 2						F 1		F 1			
85 BALL + ROLLER BEARINGS					I 1	I 1											
86 FANS FURN + OTH GENL INDSTMACH	I 1	B 1	F 1			I 4			F 1			B 1		F 1			
87 MACHINE SHOP PRODUCTS	I 1	I 1				I 1											
88 COMPUTING + RELATED MACHINES	F 1	B 2	F 1	F 2		F 1	F 1	F 1	F 1			F 2	I 7	F 1			
89 TYPEWRITERS + OTH OFF MACH NEC		B 1															
90 REFRIG MACHINERY	I 2	I 2	F 1	I 4		F 1			F 1					F 1			
91 OTH SERVICE INDUS MACHINES		B 1	F 1	F 1		B 2						F 1	I18	F 1			
92 ELEC MEAS INSTR				F 1													
93 TRANSF SWITCHGR + BOARD APPAR				I 5		I 2			F 1					F 1			
94 MOTORS CONTROL + ELEC PROD NEC	I 1			I 4		I 1											
95 HOUSEHOLD APPLIANCES	F 3	B 1	F 3	F 2	F 1	F 4	F 1	F 1	F 2		F 2	F 2	I 8	F 6	F 1	F 1	F 1
96 ELEC LIGHTING + WIRING EQUIP	I 2			I 2	F 1	I 1	I17	I24				I 6		I 2			
97 RADIO + TV RECEIVING SETS	F 1	F 1	F 1	F 2				F 1	F 1		F 1	F 2		F 1			
98 PHONOGRAPH RECORDS																	
99 TELEPHONE + TELEGRAPH APPARAT				B 1		I 3											

Table III-3 (Concluded)

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M.TITANIUM	MMTITANIUM	TUNGSTEN	CAST.ZINC	GALV.ZINC	COAL	NAT. GAS	PETROLEUM
100 RADIO + TV COMMUNICATION EQUIP	B 1	B 1	F 1	F 2	F 1	B 2		F 1	F 1	F 1		F 2	B 2	F 1			
101 ELECTRON COMPON + ACCESS	I 1	I 1		I 2								I 7					
102 ENGINE ELEC EQUIP				I 2													
103 BATT XRAY + OTH ELEC EQUIP				B 1	I49			I 4	F 1			F 1	I 7	B 1			
104 TRUCK + BUS BODIES + TRK TRAIL	B 2	B 1				B 1			F 1					B 1			
105 MOTOR VEHIC + PARTS	F15	F22	F17	F13	F 6	F15	F 4	F 6	F13	F 2	F 7	F12	I39	F15	F 7	F 4	F 4
106 AIRCRAFT - COMPLETE	F 2	A 2	F 1	F 1		F 2			F 1	I26		F 1		F 1			
107 AIRCFT ENGN + PRT INC FOR MISS	B 1	B 1	F 1			B 3			F 1	I51		F 2		F 1			
108 AIRCRAFT EQUIP + PARTS NEC	B 1	B 1	F 1			B 1			F 1	F 4		F 1		F 1			
109 SHIPBLOG + REPAIRING	F 1	F 1				I 3			F 1			F 1					
110 LOCOM RR STREET CARS + PARTS		B 1	F 1			F 1			F 1			F 1			F 1		
111 TRAILER COACHES	B 4	F 1		F 1										B 1			
112 OTHER TRANSPORTATION EQUIP NEC		F 1												B 1			
113 SCI INSTRUM MEAS + CONTROLS	B 1			I 2		I 2						F 1		F 1			
114 SURG DENT MED SUPPLIES + EQUIP							I 6	B 1									
115 WATCHES CLOCKS + PARTS																	
116 OPTIC OPTHAL GOODS INC LENSES																	
117 PHOTO EQUIP + SUPPLIES								I25	F 1				I 4	1 2			
118 MISC MANUFACTURING	B 1	F 1	F 2	B 2	B 2	I 4	I13	I25	F 3		B 8	F 1	I 6	F 6	F 1	F 1	F 1
119 RAILROADS + RELATED SERVICES																	I 3
120 MOTOR FRGT TRANSP + WAREHSNG																	I19
121 WATER TRANSPORTATION																	I 4
122 AIR TRANSPORTATION										F 1							111
123 PIPELINE TRANSPORTATION																I 6	I 1
124 LOACL PASS + OTHER TRANSP																	B 2
125 COMMUNICATIONS EX RADIO + TV																	
126 RADIO + TELEV BROADCASTING																	
127 ELEC UTILITIES							F 1				F 1				I62	I23	I16
128 GAS UTILITIES																F 2	
129 WATER + SANITARY SERVICES															F 1	B 1	
130 WHOLESALE + RETAIL TRADE	F 1	F 1	F 1	F 1	F 1	F 1	F 2	F 2	F 1	F 1	F 2	F 1	F 1	F 1	F 1	F 2	F 3
131 RETAIL TRADE	F 1	F 1	F 1	F 1	F 2	F 1	F 2	F 2	F 2		F 4	F 1	F 1	F 1	F 6	F10	F 5
132 FINANCE + INSURANCE							F 1	F 1	F 1		F 1				F 1	F 2	F 1
133 OWNER OCCUPIED DWELLINGS	F 1	F 1	F 1	F 1	F 1	F 1	F 1	F 1	F 1		F 5			F 1		F 2	F 1
134 REAL ESTATE	F 1	F 1	F 1	F 1	F 1	F 1	F 1	F 1	F 1		F 3	F 1		F 1	F 1	F 1	A 2
135 HOTELS + LODGING PLACES																B 1	
136 PSNL + REPAIR SERVICES EX AUTO		F 1	F 1	F 1	F 1	F 1	F 1	F 2	F 1		F 1	F 1	F 1	F 1	F 1	F 1	F 1
137 ADVERTISING																	
138 MISC BUSN SERVCS EX ADVERTSG			F 1					F 1			F 1					I 2	F 1
139 AUTO REPAIR + SERVICES	F 1	F 1	F 1	F 1	F 1	F 1			F 1		F 1	F 1	F 1	F 1	F 1	F 1	F 1
140 AMUSEMENTS								F 1									
141 MED + EDUC SRVS - NONPRF ORG	F 1	F 1	F 1	F 1	F 1	F 1	F 3	F 3	F 1		F 2	F 1	F 1	F 1	F 5	F 8	F 4
142 FED GOVT ENTERPRISES															I 1		
143 STATE + LOCAL GOVT ENTERPRISES															I 2		
144 IMPORTS																	
145 BUSINESS TRAV ENTERTAIN + GIFT																	
146 OFFICE SUPPLIES								F 1			F 1						
147 SCRAP USED + SECONDHAND GOODS																	
148 GOVT COMPENSATION																	
149 REST OF THE WORLD INDUSTRY																	
150 HOUSEHOLD INDUSTRY																	

Table III-4

PERCENTAGE OF DOD CONSUMPTION OF 17 MATERIALS BY SECTOR

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M.TITANIUM	NMTITANIUM	TUNGSTEN	CAST.ZINC	GALV.ZINC	COAL	NAT.GAS	PETROLEUM
1 LIVESTOCK																	
2 OTHER AGRICULTURE																	
3 FORESTRY AND FISHERY PRODUCTS																	
4 AGRIC FOREST + FISH SERVICES																	
5 IRON + FERROALLOY ORES MINING																	
6 COPPER ORE MINING																	
7 NONFERROUS METAL ORES MINING																	
8 ANTHRACITE COAL																	
9 BITUMINOUS COAL															I 2		
10 CRUDE PETROLEUM																I 5	
11 NATURAL GAS																I 1	
12 NATURAL GAS LIQUIDS																I 4	
13 STONE + CLAY MINING + QUARRY																	
14 CHEM + FERTILIZ MINERAL MINING																	
15 NEW CONSTRUCTION	F 5	F 5	F 3	F 8	F 2	F 2	F 4	F 4	F 4		F 7	F 1	F 1	F 4	F 4	F 3	F 3
16 MAINT + REP. CONST RESID BLDG											F 4						
17 MAIN. + REPAIR CONST. ALL OTHE	F 3	F 3	F 2	F 4	F 1	F 2	F 3	F 3	F 3		F17	F 1	F 1	F 3	F 2	F 2	F 4
18 COMPLETE GUIDED MISSLES	F 5	F 5	F 5	F 4	F 1	F 4	F 2	F 3	F 4	F13	F 4	F 8	F 1	F 8	F 4	F 4	F 3
19 TANK + TANK COMPONENTS	F 4	F 1	F 7	F 2	F 1	F 1	F 1	F 1	F 4	F 1	F 1	F 8	B25	F 2	F 4	F 3	F 1
20 AMMUN. INC FOR SMALL ARMS	F22	F 3	F 7	F12	I48	F 2	F 8	F 4	F12	F 1	F 3	F15	F 2	F 6	F 8	F 7	F 4
21 OTHER ORDNANCE + ACCESSORIES	F 1	F 1	F 3	F 1	F 1	F 2	F 1	F 2	F 2		F 1	F 1	F 1	F 5	F 2	F 2	F 1
22 ALCOHOLIC BEVERAGES																	
23 PROCESSED FOODS EX ALCOHOL									F 1		F 1					F 1	F 1
24 TOBACCO MANUFACTURES																	
25 BROAD + NARROW FABRICS YARN																	
26 MISC TEXTILE GOODS + FLOOR COV											I 1						
27 APPAREL																	
28 MISC FABRIC TEXTILE PRODUCTS																	
29 LUMB + WOOD PROD EX CONTAINERS																	
30 WOODEN CONTAINERS																	
31 HOUSEHOLD FURNITURE																	
32 OTHER FURNITURE AND FIXTURES																	
33 PULP PAPER + PAPERBD MILLS															I 2	I 2	
34 PAPER PROD. EX CONTAIN + BOXES											I15						
35 PAPERBOARD CONTAINERS + BOXES																	
36 PRINTING AND PUBLISHING							F 1	F 1	B 1		F 1				F 1	F 1	F 1
37 INDUS CHEM EX ALUMINA		I 5	I25		I 2	I 1	I53	I 3	I 5		F 1	I 1		B 1	I 4	I14	I12
38 FERTILIZERS + AGRIC CHEM																	
39 MISC CHEM PRODUCTS		B 1	F 2				F 3		F 1		F 5				F 1	B 1	B 1
40 PLASTICS MATERIALS + RESINS							F 1				I11					I 1	
41 SYNTH RUBBER																	
42 CELLULOS + NONCELLULOS FIBERS															I 1		
43 DRUGS																	
44 CLEANING PREPARATIONS																	
45 TOILET PREPARATIONS																	
46 PAINTS AND ALLIED PRODUCTS					I 1						I59			I 1			
47 PETROLEUM REFINING		F 1	F 1		I11	F 1	I23	F 1	F 1		F 2			F 1	F 2	F18	I13

Table III -4 (Continued)

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M.TITANIUM	N.TITANIUM	TUNGSTEN	CAST.ZINC	GALV.ZINC	COAL	NAT. GAS	PETROLEUM
48 PAVING + ASPHALT MATERIALS																	I 5
49 TIRES + INNER TUBES																	
50 OTHER RUBBER + MISC PLASTICS			F 1				F 1				I 5			I 5	F 1	F 1	F 1
51 LEATH TANN + INDUST LEATH PROD																	
52 FOOTWEAR + OTHER LEATH PROD																	
53 GLASS AND GLASS PRODUCTS								I 1								I 1	
54 STONE AND CLAY PRODUCTS		I 6					I 3				I 2				I 2	I 2	
55 BLAST FURN + BASIC STEEL PROD	I 1		I 5						I24			I 1			I36	I 5	I 1
56 IRON + STEEL FOUNDRIES			I21			I 1										I 1	
57 IRON + STEEL FORGINGS												I 1					
58 PRIMARY IRON + STEEL PROD NEC																	
59 PRIMARY COPPER																	
60 PRIMARY ZINC																	
61 PRIMARY ALUMINUM INC ALUMINA																I 2	
62 OTH PRIME NONFERR MET INC LEAD					I 1				I 5								
63 SECOND NONFERR METALS					I 4			I14	I36								
64 COPPER ROLLING + DRAWING	I 1				I 1				I14					I10			
65 ALUM ROLLING + DRAWING									F 1					I 1		I 1	
66 OTH NONFERR ROLLING + DRAWING									I 4			I11		I 2			
67 NONFERR WIRE DRAW + INSULATING	I 6			I20	I 2			F 1	F 2					F 1			
68 ALUM CASTINGS														I 6			
69 BRASS BRONZE + COPPER CASTINGS	I 1													R 1			
70 NONFERR CASTINGS NEC	I 1		I16		I 2									I39			
71 NONFERR FORGINGS																	
72 METAL CONTAINERS	I 2								I 7								
73 HEAT + PLUMB PROD EX ELECTRIC		I 1		I 1		I 2											
74 FAB STRUC SHEET + OTH MET PROD	I 6	I 5		I 1		I 3								I 2			
75 SCREW MACHINE PRODUCTS		I 5		I 6		I 2											
76 METAL STAMP INC AUTOMOBILES	I 3	I 6		I 1		I 2			I 1					I I			
77 OTHER FABRICATED METAL PROD	I 4	I 5	I20	I 4	I 1	I 4		I10	I 3			I 2	I 4	I20			
78 ENGINES + TURBINES	B 1	I 2	F 2	B 1		B 1			F 1			I 2		F 2	F 1		
79 FARM MACHINERY																	
80 CONSTR MIN + OILFIELD MACHINRY		B 1	F 1			B 1			F 1			B 2	I 2	F 1	F 1		
81 MATERIALS HANDL MACHIN + EQUIP		B 1	F 1						F 1			F 1		F 1	F 1		
82 METALWORK MACHIN + EQUIP		I 3	I11	I 1		I 1						I35					
83 SPECIAL INDUS MACHIN + EQUIP						I 1											
84 PUMPS + COMPRESSORS		I 1				I 1											
85 BALL + ROLLER BEARINGS		I 1			I 1	I 1											
86 FANS FURN + OTH GENL INDSTMACH		B 1				I 2								F 1			
87 MACHINE SHOP PRODUCTS	I 1	I 3		I 1		I 2						I 1					
88 COMPUTING + RELATED MACHINES	F 1	R 2	F 1	R 1			F 1	F 2	F 1		F 1	F 1	I 9	F 1	F I		
89 TYPEWRITERS + OTH OFF MACH NEC																	
90 REFRIG MACHINERY	I 1	I 1		I 2													
91 OTH SERVICE INDUS MACHINES													I 6				
92 ELEC MEAS INSTR				B 1		B 1		F 1	F 1								
93 TRANSF SWITCHGR + BOARD APPAR				I 4		I 1								F 1			
94 MOTORS CONTROL + ELEC PROD NEC	B 1	B 1	F 1	I 5		B 1	F 1	F 1	F 1		F 1	F 1		F 1	F 1		
95 HOUSEHOLD APPLIANCES													I I				

Table III-4 (Concluded)

	ALUMINUM	CHROMIUM	COBALT	COPPER	LEAD	NICKEL	PLATINUM	SILVER	TIN	M.TITANIUM	NMTITANIUM	TUNGSTEN	CAST.ZINC	GALV.ZINC	COAL	NAT.GAS	PETROLEUM
96 ELEC LIGHTING • WIRING EQUIP	I 1			I 1		I 1	I14	I22				I 2		I 1			
97 RADIO • TV RECEIVING SETS																	
98 PHONOGRAPH RECORDS																	
99 TELEPHONE • TELEGRAPH APPARAT				B 2		I 3			F 1								
100 RADIO • TV COMMUNICATION EQUIP	F 9	F10	F 7	F16	F 4	F17	F 6	F10	F 8	F 1	F 6	F12	F22	F11	F 6	F 5	F 4
101 ELECTRON COMPON • ACCESS	I 2	I 2	F 1	I 7		I 1	F 1	F 1	F 1		F 1	I14		F 1	F 1	F 1	F 1
102 ENGINE ELEC EQUIP				I 3													
103 BATT XRAY • OTH ELEC EQUIP				B 1	I25		F 1	I 5	F 1				I 7	B 1			
104 TRUCK • BUS BODIES • TRK TRAIL	B 1													B 1			
105 MOTOR VEHIC • PARTS	F 4	F 7	F 5	F 4	F 1	F 3	F 2	F 3	F 5		F 4	F 2	118	F 5	F 4	F 2	F 2
106 AIRCRAFT - COMPLETE	F12	F17	F 7	F 7	F 2	F 9	F 2	F 5	F 8	I27	F 5	F 7	F 2	F 9	F 6	F 5	F 3
107 AIRCFT ENGN • PRT INC FOR MISS	F 6	F12	F 9	F 3	F 2	I21	F 2	F 4	F10	I63	F 3	F12	F 1	F10	F 6	F 4	F 3
108 AIRCRAFT EQUIP • PARTS NEC	111	B11	F 6	F 4	F 2	F 7	F 2	F 3	F 6	F 5	F 3	F 6	F 1	F 7	F 5	F 3	F 2
109 SHIPBLDG • REPAIRING	F 4	F 6	F 4	F 4	F 1	F14	F 1	F 2	F 6		F 3	F 3	F 1	F 4	F 4	F 2	F 2
110 LOCOM RR STREET CARS • PARTS																	
111 TRAILER COACHES																	
112 OTHER TRANSPORTATION EQUIP NEC																	
113 SCI INSTRUM MEAS • CONTROLS	B 1		F 1	B 3		B 2	F 1	F 1	F 1		F 1	F 1		F 1	F 1		
114 SURG DENT MED SUPPLIES • EQUIP							I 4	B 1									
115 WATCHES CLOCKS • PARTS																	
116 OPTIC OPTHAL GOODS INC LENSES																	
117 PHOTO EQUIP • SUPPLIES							F 1	I37	F 1				I 5	B 2			
118 MISC MANUFACTURING							I 3	I 6			I 2		I 1	I 1			
119 RAILROADS • RELATED SERVICES																	I 3
120 MOTOR FRGT TRANSP • WAREHSNG							F 1				F 1					F 1	I21
121 WATER TRANSPORTATION											F 1				F 1		I 6
122 AIR TRANSPORTATION							F 1									F 1	I18
123 PIPELINE TRANSPORTATION																I 7	
124 LOACL PASS • OTHER TRANSP																	I 1
125 COMMUNICATIONS EX RADIO • TV																	
126 RADIO • TELEV BROADCASTING																	
127 ELEC UTILITIES															I46	I14	I 8
128 GAS UTILITIFS																	
129 WATER • SANITARY SERVICES																	
130 WHOLESALE • RETAIL TRADE							F 1	F 1			F 1				F 1	F 1	B 1
131 RETAIL TRADE																I 1	
132 FINANCE • INSURANCE																	
133 OWNER OCCUPIED DWELLINGS																	
134 REAL ESTATE																	I 1
135 HOTELS • LODGING PLACES											F 1				F 1	F 2	F 1
136 PSNL • REPAIR SERVICES EX AUTO																	
137 ADVERTISING																	
138 MISC BUSN SERVCS EX ADVERTSG	F 1	F 1	F 2	F 1	F 1	F 1	F 2	F 4	F 2		F 3	F 1	F 2	F 2	F 2	F 4	F 3
139 AUTO REPAIR • SERVICES																	
140 AMUSEMENTS																	
141 MED • EDUC SRVS - NONPRF ORG							F 1	F 1			F 1				F 2	F 3	F 1
142 FED GOVT ENTERPRISES															B 1		F 1
143 STATE • LOCAL GOVT ENTERPRISES															I 1		
144 IMPORTS																	
145 BUSINESS TRAV ENTERTAIN • GIFT																	
146 OFFICE SUPPLIES							F 1	F 2			F 2						
147 SCRAP USED • SECONDHAND GOODS																	
148 GOVT COMPENSATION																	
149 REST OF THE WORLD INDUSTRY																	
150 HOUSEHOLD INDUSTRY																	

letter "F" designates the material consumed by all industries to produce the final demand from that sector.

If both types of consumption are at or above 1 percent, then only the higher consumption is shown. This is the consumption labeled "final demand" in Figure III-1. The letter "B" indicates that both types of consumption are equal within 1 percent.

The usefulness of these two tables lies in the provision of visual recognition of the sectors that are important contributors to U.S. or DoD consumption for many or all of the materials. Thus, sector 15, new construction, and sector 105, motor vehicles, account for a significant degree of U.S. consumption for almost all the 17 materials. Sectors 18-21, the ordnance sectors, and sectors 106-109, the aircraft sectors, are significant consumers for DoD for all the materials. Sectors that are important for individual materials can also be easily identified. Thus, industrial chemicals, sector 37, requires 42 percent of U.S. platinum consumption and 27 percent of cobalt. An example of DoD consumption is that 63 percent of the metallic titanium is used for aircraft and missile engines, sector 107.

IV THE ECONOMIC IMPACTS OF MATERIAL AND ENERGY RESOURCE SHORTAGES

A. Introduction

In Section III an approach to understanding and characterizing the flow of materials through the economy was presented. This material flow approach has been applied to show how material requirements are met by industrial sectors supplying products to both DoD and civilian final demand. For many planning purposes, the materials flow information is directly useful in the form presented in Section III. The objective of the work described in the present section is to extend the usefulness of the material flow information by developing an approach that defines and clarifies economic problems associated with possible resource shortages.

The objectives of the research were to determine and analyze

- the effects of specific resource shortages on GNP and the relative sensitivity of GNP to shortages of different resources
- the effect on GNP of reducing both civilian and DoD final demand for the outputs of specific industrial sectors during resource shortages
- the effects on GNP of a simultaneous shortage of more than one resource
- the effects of possible shortages on DoD needs for materials and energy resources.

Within the limitations of the analysis, the results of the study should be useful to the DoD in its planning efforts as they relate to potential future shortages. For DoD to best address material shortage issues, it is first essential that the impacts of shortages on the economy be understood. General economic analysis is needed for the DoD to better evaluate (1) measures, such as stockpiling policies, that will best protect defense supplies in the event of shortages, (2) ways in which the Defense Production Act can be applied during a shortage so that its adverse impacts on

the economy can be minimized, (3) measures that can be applied to reduce the defense final demand for specific products so as to lessen adverse economic impacts during a shortage, and (4) the likelihood that industrial sectors of the economy that supply DoD with important products will be affected by a given resource shortage. The general point is that DoD can most effectively anticipate the impacts of shortages if it has addressed issues relating both to its own use of material and energy resources and to the interactions between its uses and those of the civilian economy, on which DoD is dependent.

B. Method of Approach: Conceptual Overview

Figure IV-1 presents an overview of the methodology used in addressing economic impacts of resource shortages. Each of the elements of the analysis is indicated in the boxes in the figure, which are numbered from one to eight.

The problem is formulated as a series of linear equations subject to linear constraints. The linear program formulation allows us to determine the minimum or maximum of a given quantity, called the objective function, consistent with the constraints that serve to define important aspects of the problem. The objective function is gross national product, as indicated in element 6 of Figure IV-1. The constraints include the relationships describing material flows through 150 sectors of the economy (elements 1 and 2); the magnitude of the shortage for the given computer run, which is the key variable whose impacts are investigated in the analysis (element 5); the capacity constraints, which specify the maximum output of each of the 150 industrial sectors (element 3); and the final demand constraints, which specify the minimum final demand for the outputs of the 150 industrial sectors (element 4). The output of the calculation is the sensitivity of GNP to the resource shortage and the impacts of the shortage on each of the industrial sectors (elements 7 and 8).

Although the mathematical formulation of the problem and the establishment of the data base, explained in the next part, are somewhat complicated, the functioning of the model is straightforward. The information in elements 1 and 2 of Figure IV-1, used in Section III to generate

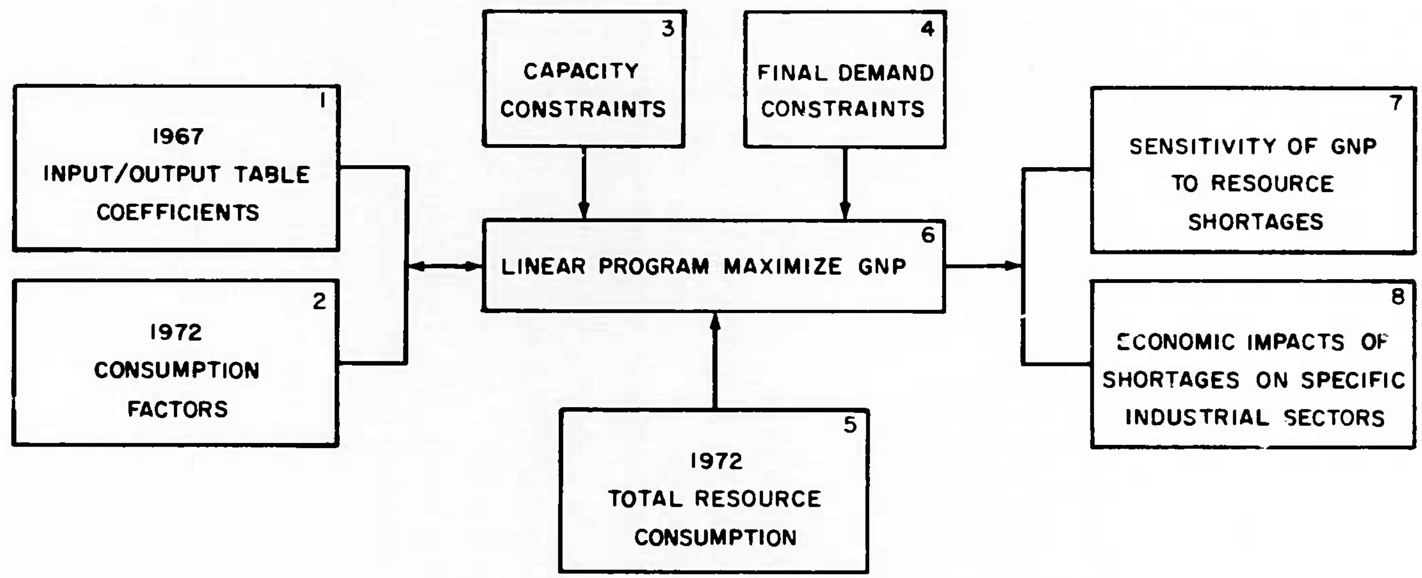

FIGURE IV-1. CONCEPTUAL APPROACH TO ECONOMIC ANALYSIS OF SHORTAGES

material flow diagrams (such as shown in Figures III-3 through III-6), specifies the relationships among material flows, final demand, and industrial output of the 150 industrial sectors in the absence of a resource shortage. This relationship translates a given level of final demand for the products of 150 industrial sectors into the gross outputs of the industrial sectors* (using the input-output table), which are then converted into material requirements. During a resource shortage, we assume that the same relationships apply; what changes are the final demands, since not enough material is available during a shortage to fulfill the base case final demand. The linear program routine calculates a new set of final demands that would maximize GNP during the shortage (or equivalently, minimize the reduction in GNP). By determining the new set of final demands for the output of the industrial sectors during the resource shortage, the linear program solution calculates the resource requirements during the shortage (since resource requirements and final demand are related by the input-output table).

In short, the linear program approach consists of the following elements:

1. The specification of the shortage case to be analyzed, in terms of the resource of resources in short supply and the amount of the shortage (element 5 in Figure III-1).

2. The specification of linear constraints:

    a. Relationships between final demand, gross output, and material consumption of 150 industrial sectors (elements 1 and 2).

    b. Maximum industrial gross outputs (element 3) and minimum final demand (element 4) for the products of the industrial sectors.

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*As discussed in Section III, final demand is that part of the output of an industrial sector that is purchased by the consumer; gross output includes also the output that is purchased by other industrial sectors (to fulfill what is termed intermediate demand).

3. The selection and maximization of an objective function (GNP as shown in Element 6) subject to the linear constraints.

4. The results of the calculation, analyzed in terms of the effects of the different shortages on GNP and on the output of the industrial sectors (elements 7 and 8); the results are also analyzed in terms of the effects on GNP of reducing the final demand for specified outputs below the levels set by the minimum final demand constraints.

C. Method of Approach: Mathematical Formulation of the Resource Shortage Model and Determination of Constraints

1. Model Formulation

The equations and inequalities that describe the linear programming model are shown in Table IV-1 below.

Table IV-1

MATHEMATICAL FORMULATION OF MATERIAL AND ENERGY RESOURCE SHORTAGE MODEL

Equation	Description	
$V \cdot X = GNP$	Objective function to be maximized	(1)
$(I - A) \cdot X \geq Y_{min}$	Minimum final demand constraints	(2)
$M \cdot X \leq M_{tot}$	Material supply constraints	(3)
$X \leq X_{max}$	Industry output capacity constraints	(4)

The symbols used in Table IV-1 are defined as follows:

V = value added per unit output (150-component vector in \$/\$)

X = gross industrial output (150-component vector in \$)

Y = final demand (150-component vector in \$)

A = interindustry direct coefficients (150 x 150 matrix in \$/\$)

M = material consumed per unit output (one 150-component vector for each material in quantity of material /\$).

Using the equations and inequalities given in Table IV-1, we can describe how the material and energy resource model works more concisely. The parameter M_{tot}, which is the amount of a material available for consumption, is chosen to describe the shortage case of interest. Since the vector M, the material consumed per unit output of the industrial sectors, is constant, the inequality constraint (3) requires that the gross outputs of the industrial sectors must change in response to the reduced availability of the resource. Equation (1) specifies that this adjustment in the industrial gross outputs be accomplished so as to maximize GNP. Since GNP is the sum of value added terms for all industrial sectors, equation (1) and inequality (3) attempt to maximize the gross outputs of those industrial sectors whose use of the scarce resource most increases the value added (i.e., those sectors for which the quantity V/M, value added per unit amount of material consumed, is highest). Similarly, for those industrial sectors with a small value added per unit of material, equation (1) and constraint (3) attempt to reduce the gross outputs to minimum values.

In the absence of additional inequality constraints (2) and (4), the gross output of the sector with the highest value added per material consumed would go as high as possible (i.e., it would take on a value of M_{tot}/M, which would enable this one sector to consume all of the available material). Of course, even if the output of just one industrial sector could grow so rapidly as this, such a solution is clearly impossible as it it implies that all other sectors that require the material in short supply have reduced their output to zero. The constraint inequalities (2) and (4) introduce minimum bounds on final demand and maximum bounds on gross output, as well as specify the dependencies of an industry on the outputs of other industries in order for the economy to function. Thus, the final demand, gross output, and dollar and material flow constraints are needed to insure that the solution of the problem is consistent with reasonable requirements and capabilities of the U.S. economy. In the following paragraphs we describe how these constraints have been set.

2. Establishing the Upper Bounds on Gross Output and the Lower Bounds on Final Demand

There is no obvious or established procedure for setting the upper bounds on gross output or the lower bounds on final demand. The upper bounds on gross output represent the amount by which an industry can increase its output within a time frame of one year. Since most industries cannot build new capital facilities within this period of time, the increase in output is primarily determined by the fraction of total capacity available to the industry that was used in the base year. We have used capacity utilization ratios compiled in reference 7 as the source of our maximum capacity constraints. The results of the calculation were independent of these capacity constraints, since no outputs were at the upper bounds during a severe materials shortage. As a result, the selection of the maximum capacity constraints was not critical for the calculations that we have performed.

The selection of final demand constraints, on the other hand, has a significant influence on the results of the calculation. The linear program routine without minimum final demand constraints attempts to maximize GNP by reducing final demand for products whose production contributes least to GNP per unit of scarce material required to manufacture them. As a result, the methodology tends to reduce final demand to zero for the output of some or many industries in the absence of minimum bounds on final demand. As noted earlier, such a solution to the problem of reducing the effect of the shortage on GNP is unrealistic since it implies that the industries most affected by the shortage would be put in serious jeopardy, causing severe economic disruption, unemployment, and so forth.

As a case in point, suppose that a shortage of aluminum occurred and the packaging industry, which requires a large quantity of aluminum for cans, was adversely impacted during the period of shortage. In a calculation without minimum final demand constraints, the packaging industry would be likely to feel the impacts of the shortage considerably more than other industrial sectors, since one unit of aluminum allocated to this industry contributes less to GNP than the same unit allocated to many other industrial sectors. At some point, however, both the consumer,

who is used to purchasing products in aluminum cans produced by the packaging sector, and the packaging industry output would be sufficiently affected by the shortage that some minimum demand would not be satisfied. For the packaging industry, this minimum demand is defined by its historical pattern of output and by an adequate level of sales to avoid going out of business or undergoing massive layoffs. For the consumer, this minimum final demand level is not so easily defined, but it is related in some manner to the historical level of purchases of industrial products to which the consumer has become accustomed.

A set of self-consistent minimum final demand constraints could possibly be derived by an extensive and detailed examination of the production histories of and consumer behavior toward the products of the industrial sectors. In the absence of such knowledge, we have chosen to use historical demand patterns for the outputs of the industrial sectors as a basis for establishing the final demand constraints. The procedure that we followed was to plot the final demand for industry outputs for the years 1958-1972. This information is available from reference 8. A linear least squares line was fitted to the data, and lines were drawn parallel to this in increments of 1 standard deviation from the least square fit.

Figures IV-2 and IV-3 illustrate the procedure for establishing the lower bounds on final demand for the outputs of industrial sector 55, electric lighting and wiring, and sector 56, radio, television, and communications equipment. The final demand constraints 4.5 and 5.5 standard deviations below the least squares fit are shown. A comparison of Figures IV-2 and IV-3 provides an explanation of the rationale for the procedure we have used to establish minimum final demand constraints. The demand for electric lighting and wiring, a necessity to the construction industry, does not deviate greatly from the least squares line. As such, the minimum final demand, at 5 standard deviations below the line, is approximately 80 percent of the final demand for the base year, 1972. The demand for radios, televisions, and communications equipment, many of which are luxury items, exhibits a high degree of variation from the least squares fit. As a result, the minimum final demand for 1972 is only about 30 percent of the base year, 1972, at 5 standard deviations below the line.

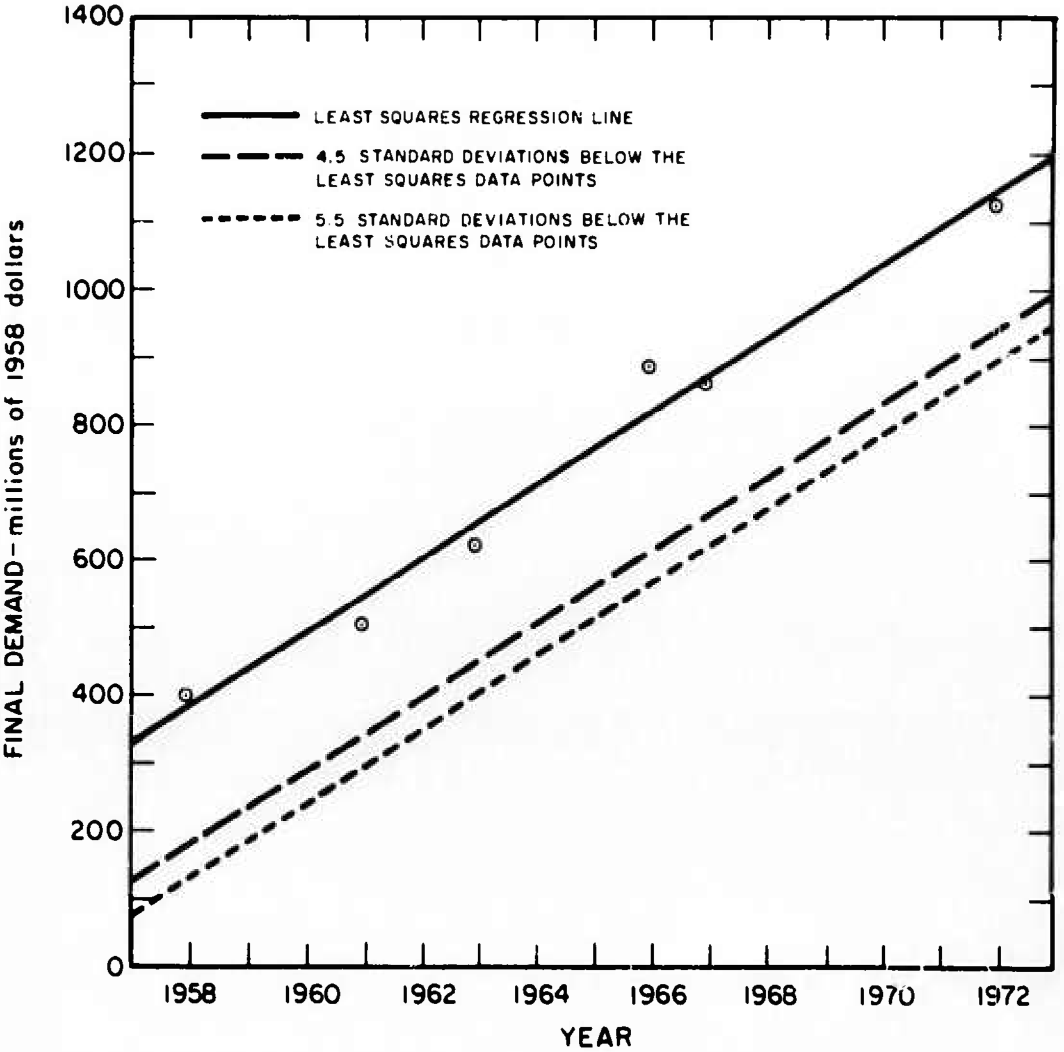

FIGURE IV-2. MINIMUM FINAL DEMAND CONSTRAINTS FOR SECTOR 96 -- ELECTRIC LIGHTING AND WIRING

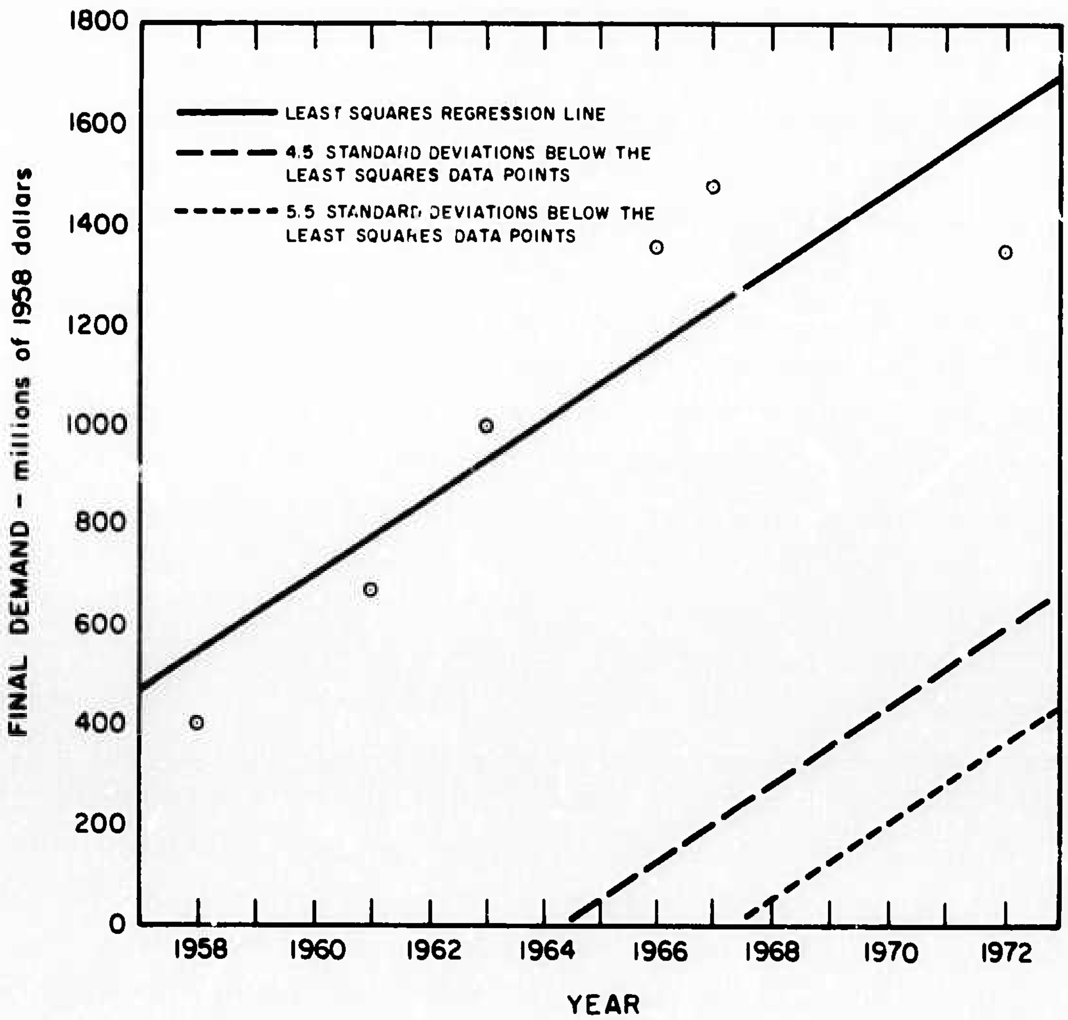

FIGURE IV-3. MINIMUM FINAL DEMAND CONSTRAINTS FOR SECTOR 97 -- RADIO, TV, COMMUNICATIONS EQUIPMENT

The foregoing discussion thus establishes a procedure for approximating the minimum final demand constraints for the different sector outputs as a function of the number of standard deviations removed from the least squares fit of the historical data. The question then arises as to how many standard deviations should be chosen to determine a reasonable solution to the allocation problem during a shortage. As indicated later, we have chosen to use 5 standard deviations, as this number provides the best fit between the results of the petroleum shortage calculation and the data gathered during the Arab oil embargo of 1973-74. There is some uncertainty in the determination of this parameter, since the economic impacts of the embargo may provide somewhat low estimates of the economic impacts of the embargo. However, analysis of the results has shown that the relative degree to which industries are affected by a shortage is generally independent of the final demand constraints, so long as they are set in the consistent way outlined above. That is, the relative economic impacts for the set of final demand constraints 2 standard deviations below the least squares line of the final demand for products of all industrial sectors are qualitatively the same as the relative impacts for the case in which the final demand constraints are 5 standard deviations below the line. The absolute effect (i.e., GNP reduction as a function of the percentage shortage of a given material) does vary with the "tightness" or "looseness" of the final demand constraints. However, the relative impacts of shortages of different materials on the key industrial sectors are invariant to the final demand constraint selection, if they are set in the manner described. These considerations are extremely important in the interpretation of the range of validity of the results of the model calculation.

D. Assumptions and Approximations of the Material and Energy Resource Shortage Model

As for all model calculations, we have had to make several assumptions and approximations to achieve results. This section summarizes these assumptions and approximations.

1. Data Limitations

The model has been applied to 17 material and energy resources. This set of resources was chosen because of the availability of resource consumption data by different industries. In principle, the analysis could be extended to other materials for which consumption estimates by industry have been compiled by the U.S Bureau of Mines. In practice, however, the consumption estimates are not sufficiently disaggregated for use in the model. Thus, more detailed information about the consumption of resources by industrial sector would extend the usefulness of the resource shortage model.*

2. Material Substitutions

Substitution of materials is not explicitly treated in the model. Because the model is meant to be applied only to a shortage of limited duration, the material substitutions are not expected to affect the shortage impacts significantly for most cases. Even for short-term shortages, substitution is likely to become increasingly important as the economic impacts become severe. Inclusion of material substitution effects would both improve the correspondence of the model calculation to economic reality and extend its usefulness in treating longer term effects of shortages.

3. Projections

Currently the model has been applied to the base year of 1972. It would be useful to extend the methodology so that some projective capabilities are achieved. A limitation of the projective work is due to the static nature of the input-output coefficients. Inasmuch as the input-output table is required by the methodology, it is unlikely that projective work further than 10 years in the future can be achieved.

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*Mr. Emil Romagnoli of the Department of Commerce has indicated that the Department of Commerce will undertake such a data gathering task in the near future.

4. Value Added

In calculating GNP as the sum of value added contributions of the industrial sectors, average value added terms from the input-output table were used. In the event of a shortage, the value added of some industrial sectors may be different from this average term. In principle, a marginal value added term might be appropriate to characterize the contribution of industrial sectors to GNP. However, obtaining information about marginal value added terms for industrial sectors would be very difficult. A useful compromise would be to choose sectors for which the marginal and average value added terms are likely to be different and perform sensitivity calculations on estimates of the marginal value added terms.

5. Objective Function

The choice of GNP as the objective function to be maximized during a shortage has advantages and disadvantages. A shortage occurring in a free market economy will cause the price of the material in short supply to rise until supply and demand are equal. This means that the market allocates the material preferentially to those industries that can afford to pay the higher price. Industries are able to pay a higher price in proportion to the contribution that the material makes to the output of the industry. For example, if one unit of aluminum is needed to produce \$2 of output of industry A and \$20 of output of industry B, it is evident that industry B can better afford the higher-priced aluminum. Maximizing GNP has the effect of allocating the material in short supply to the industries that profit most by consuming the material. Thus, the choice of GNP as the objective function is a reasonable way of simulating the effect of a shortage.

The disadvantage of the approach is that it is only an approximation to the market allocation of scarce resources. More precise quantitative results might be obtained by a model which explicitly considers the price mechanism for allocating scarce resources in a shortage situation. Our current plans for extending the model development envisage a change in the objective function to directly take account of price and market forces.

E. Results

We follow the approach of Section III in using the cases of aluminum and petroleum to illustrate the results of the model calculation. First, a detailed discussion of the economic impacts of a petroleum shortage is presented, in which the results of the model calculation are compared with data obtained during the 1973-74 OPEC oil embargo. The analysis of a petroleum shortage is used to indicate the strengths and weaknesses of the linear programming approach for treating the resource shortage problem. Then the economic impacts of an aluminum shortage are analyzed. Results for aluminum are compared with those for petroleum, and some general conclusions are drawn. Finally, results for 15 other material and energy resources are presented and analyzed.

1. Sensitivity of GNP to a Petroleum Shortage

The methodology for setting the final demand constraints, which requires that we determine one paramter (called k) specifying the number of standard deviations below the least squares fit of the historical final demand data, is used to set the lower bounds on final demand. Figure IV-4 shows the percentage reduction in GNP as a function of the percentage shortage of petroleum for values of k ranging from 2 to 6 in integer steps. These results have been obtained using a 37-sector input-output table, described in part A of the appendix.* The final demand vector and resource consumption estimates were for 1972. All dollars were constant 1967 dollars. Although the shapes of the curves are similar for all k, the magnitude of the reduction in GNP increases substantially as the value of the parameter k is reduced. Qualitatively, this is as we would expect: as k declines, the final demand constraints were made "tighter" and the linear programming maximization of GNP has less freedom to reduce the final demand of sectors whose output contributes relatively little to GNP. Quantitatively, the effect of varying k on the reduction in GNP is

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*Calculations were also performed on the 150-sector input-output table; good agreement between the 37-sector and the 150-sector results for petroleum was achieved.

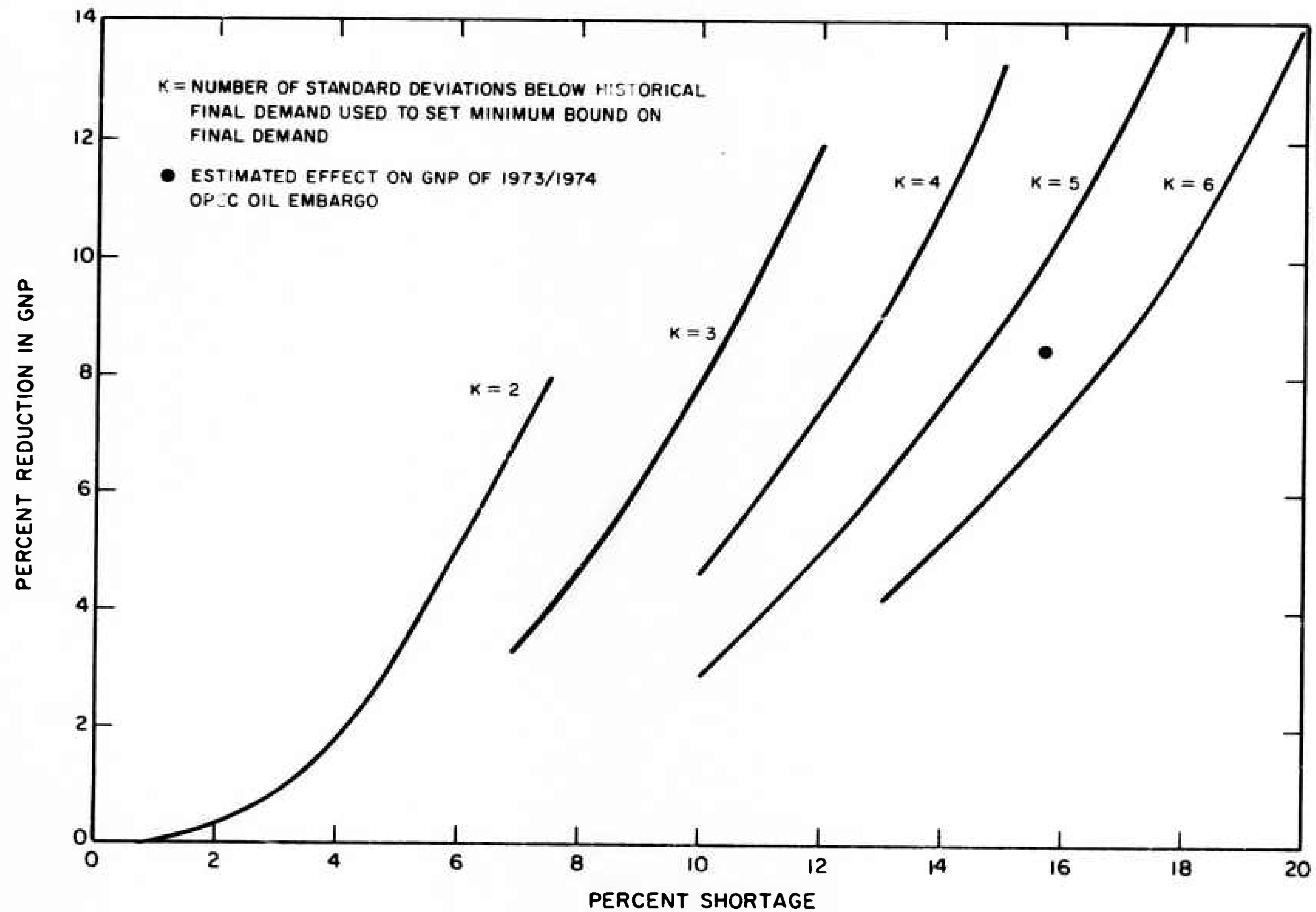

FIGURE IV-4. REDUCTION IN GNP AS A FUNCTION OF THE MAGNITUDE OF A PETROLEUM SHORTAGE FOR DIFFERENT FINAL DEMAND CONSTRAINTS

significant: at $k = 3$, the model estimates that a 10 percent petroleum shortage is responsible for a decline in GNP of 8 percent; at $k = 6$, the same 10 percent petroleum shortage causes GNP to decline only 2 percent.*

To choose a value of the parameter k for use in our calculations, we have shown on Figure IV-4 a point corresponding to the estimated effect of the 1973-74 OPEC oil embargo. Reference 9, which summarizes the economic data collected during the embargo, has estimated that a 15.7 percent shortage caused real GNP to decline 8.5 percent. We regard this figure as a lower bound estimate of the effect of the shortage on GNP as the base case GNP for this period may have been underestimated in the absence of the petroleum shortage. As a result, we have chosen $k = 5$ for the material and energy shortage calculations.

The uncertainty in the appropriate choice of k should be recognized. Data analysis of some past shortages could perhaps improve the estimate. However, the purpose of the calculation is to illustrate the relative impacts of a range of shortages and to show that these relative impacts are unchanged as k changes within reasonable bounds. It would be inappropriate to use these calculations as precise quantitative measures of the dollar costs of resource shortages. For this reason, we illustrate the impact of petroleum and aluminum shortages on GNP in Figure IV-6 for $K = 4.5$ and $k = 5.5$, thus showing uncertainty in the estimated economic effects of the shortages. We emphasize again that the primary utility of these calculations is for purposes of comparing the relative impacts of different shortages and also for indicating the industrial sectors for which a reduction in final demand will minimize adverse economic impacts of a given shortage. We turn now to this latter point.

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*As indicated previously, the qualititative results were independent of the choice of k; that is (1) the economic effects of different resource shortages relative to one another are generally independent of the value of k, and (2) the effect on GNP of decreasing final demand for the products of a given industrial sector relative to that of another industrial sector is generally independent of the value of k.

2. Reducing Final Demand During a Petroleum Shortage: An Interpretation of Shadow Prices

a. Definition of Shadow Price

The shadow price of a variable in a linear programming calculation is the dollar increase in the objective function per unit increase in the variable. Shadow prices are obtained only for those variables associated with binding constraints. The significance of the shadow price and the meaning of the term "binding constraint" can best be understood by referring to the system of inequalities and equations describing the shortage calculation given in Table IV-1. Those inequalities among the three sets--$(I - A)\cdot X \geq Y_{min}$, $M\cdot X \leq M_{tot}$, and $X \leq X_{max}$--for which the equality condition holds are said to be binding. We have already indicated that the separate elements of the gross output vector X are almost always less than the capacity constraints, X_{max}. Thus we generally obtain no shadow prices for the gross outputs. However, the inequalities for many of the final demand sectors are at lower bounds, as is the inequality for the resource in short supply.

To illustrate the meaning of the final demand shadow price, consider a hypothetical case of a three-industrial sector economy in which the final demands for the products of two of the three industries are at their minimum constraining value. Let industry A and industry B have shadow prices of 15 and 3 respectively. This means that reduction of final demand for the products of industry A reduces GNP losses by $15 for every $1 of petroleum that is reallocated to other uses. Reduction of final demand for products of industry B may also produce favorable economic impacts but not nearly so much as the reduction of final demand for products of industry A. Thus, the sectors that have the highest shadow prices for final demand are those for which final demand reductions will most effectively minimize the adverse effects on GNP at the margin (i.e., after final demand has already been reduced to its constraining value).

b. <u>Shadow Prices for Final Demand Sectors during a Petroleum Shortage</u>

The interpretation of the shadow prices obtained for petroleum shortages consists of three parts: methodology, general economic implications, and relevance to DoD planning.

The results are shown in Table IV-2, in which the final demand sectors and their shadow prices are presented for petroleum shortages of 25 percent, 18 percent, 15 percent, and 10 percent, in order of declining shadow prices. The calculation was done using the 37-sector input-output table for 1967 with k = 5. The final demand vector was for 1972. Note that:

- as the shortage becomes greater, the shadow price of a given final demand sector increases, and
- the ordering of the final demand sectors in decreasing magnitude of the shadow prices is unchanged from a 10 percent to a 25 percent shortage of petroleum.

The first observation is expected--an increasing petroleum shortage causes increasing shortages in industries whose use of petroleum contributes significantly to GNP. Thus, as the degree of shortage intensifies, the dollar loss in GNP per unit of additional shortage increases. It is for this reason that shadow prices increase at greater shortages.

The second observation derives from the fact that the relative contribution of each sector to GNP through its use of petroleum, measured by value added per unit of petroleum consumption, is independent of the level of shortage. An important third observation is that the ordering of the final demand sectors by shadow prices is unchanged as the value of k varies between 6 and 2. This shows that the general interpretation of the shadow price results are not strongly sensitive to our choice of the parameter k.

The general economic interpretation that we give to the shadow prices shown in Table IV-3 for petroleum (in Table IV-4 for aluminum and in the appendix for the other material and energy resources) is that

Table IV-2

SECTORS WHOSE FINAL DEMAND EXHIBITS THE HIGHEST SHADOW PRICES DURING PETROLEUM SHORTAGES*

Sector		Shadow Price for a Petroleum Shortage of			
Number	Name	24%	18%	15%	10%
16	Paving and asphalt materials	119	80	69	33
32	Electric utilities	18	12	5	4
12	Industrial, agricultural, and miscellaneous chemical products	15	10	6	4
29	Transportation services, communication, and water	13	8	7	3
15	Petroleum refining	11	7	6	3
30	Pipeline transportation	10	6	5	2
31	Local passenger and other transportation	10	6	5	2
14	Paints and allied products	6	4	2	1
13	Plastic, rubber, and cellulose	5	3	2	1

*Calculation performed on 37-sector input-output table; minimum final demand parameter k = 5.

Table IV-3

SECTORS WHOSE FINAL DEMAND EXHIBITS THE HIGHEST SHADOW PRICES DURING ALUMINUM SHORTAGES*

Sector		Shadow Price for an Aluminum Shortage of	
Number	Name	30%	20%
19	Fabricated metal products	43	2
27	Transportation equipment	30	2
9	Ordnance	18	1
23	Transformers, switchgear, and electric lighting	17	1
25	Trucks, buses, motor vehicles, and parts	16	1
26	Aircraft, including missiles	14	<.5
22	Computers, office and other service machinery	13	<.5

*Calculation performed on 37-sector input-output table; minimum final demand parameter k = 5.

- in the event of a shortage, demand is most likely to be reduced for products of industries whose final demands have the highest shadow prices by the action of the free market, and
- to the extent that the free market does not effectively reduce final demand for these products, a government allocation program will be most effective in reducing adverse impacts on the economy if it adopts policies to reduce the final demand preferentially for industrial products having the highest shadow prices.

As indicated in Table IV-2, those sectors with the highest shadow prices under conditions of a petroleum shortage include paving and asphalt materials; electric utilities; industrial, agricultural, and miscellaneous chemical products; transportation services, communication and water utilities; and petroleum refining. That these results are reasonable is suggested by the fact that all of the industries whose final demand exhibits a high shadow price are sectors for which the cost of petroleum represents a relatively high percentage of the total value of the product of the sector. As such, the output of the sector is expected to contribute relatively little to GNP.

We discuss now the relevance of these results to the DoD. The shadow prices contain information indicative of those final demand products and services that are likely to be in short supply during a petroleum shortage; government policy, prevailing inventories in industries, and unexpected consumer behavior will of course also impact the availability of industrial products and services during the shortage. A promising analytical tool for DoD advance planning for shortages is obtained by combining results of Table IV-2 with the petroleum flow information obtained in Section III. This is done in Figure IV-5, in which we have listed the sectors with the highest shadow prices on final demand (from the linear program solution) along with the estimated percentage of DoD and U.S. petroleum use through the consumption of the products and services of these sectors. Figure IV-5 suggests that:

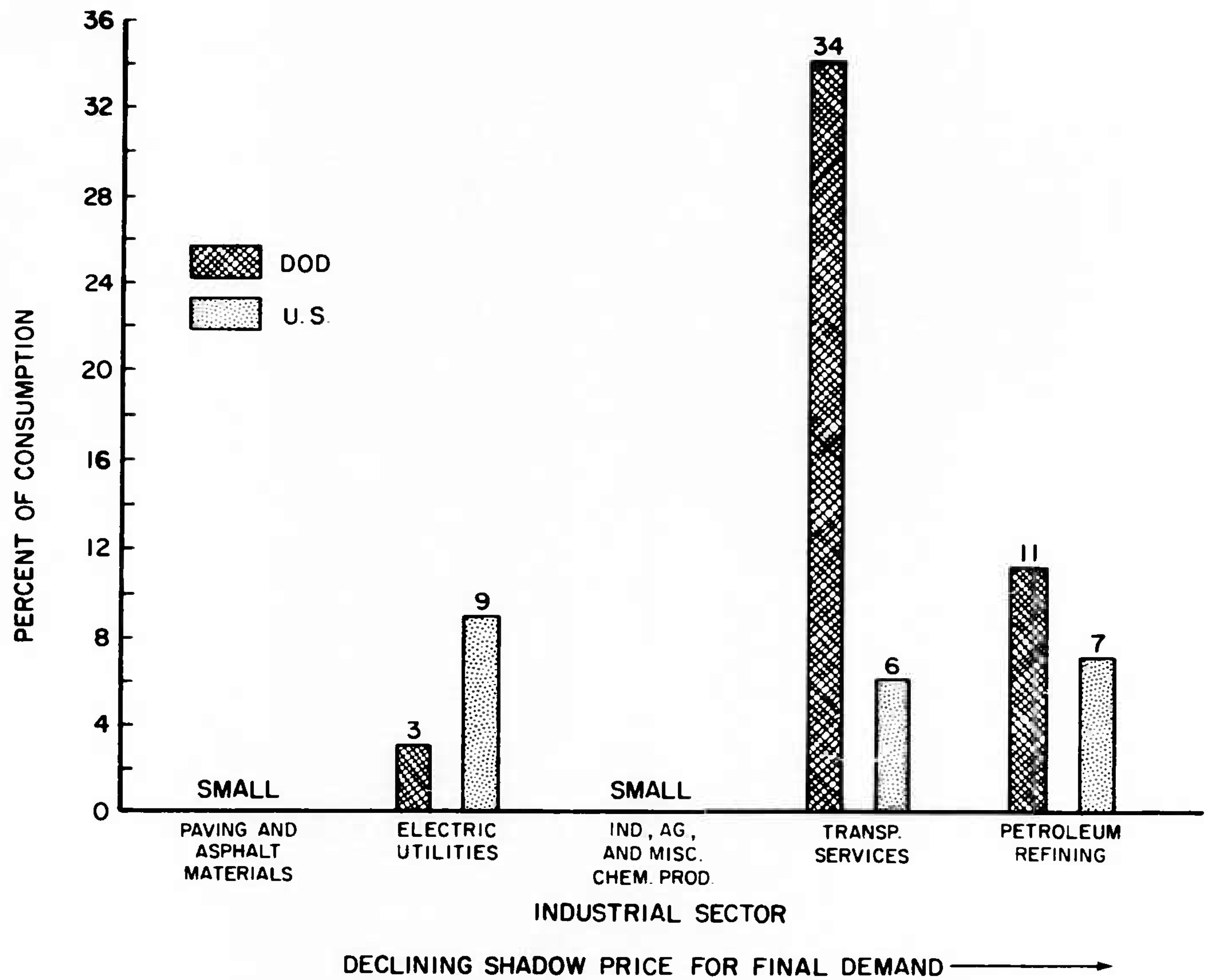

FIGURE IV-5. DOD AND U.S. PETROLEUM USE THROUGH CONSUMPTION OF PRODUCTS WITH FINAL DEMAND SHADOW PRICES DURING A SHORTAGE OF PETROLEUM

- The civilian economy is more likely than DoD to be affected by possible reductions in the availability of electricity during a petroleum shortage.
- Declining availability of petroleum for transportation services (represented by the output of the transportation service sector--petroleum products for air and rail transport--and the output of the refining sector--gasoline for automobiles and trucks) during a shortage will affect DoD considerably more than the civilian economy.

The analysis therefore suggests that DoD advance planning for a petroleum shortage should, in substantial measure, be devoted to ensuring the availability of petroleum for high-priority transportation needs, as petroleum for transportation uses is likely to be in short supply and DoD use of petroleum for transportation is high.

3. Sensitivity of GNP to a Shortage of Aluminum

The results presented in Figure IV-6 compare the reduction in GNP due to an aluminum shortage with that due to an oil shortage. The results are presented for values of the final demand parameter equal to 4.5 and 5.5, using a 37-sector input-output table and 1972 final demand and material consumption estimates. Several general observations are suggested:

- At comparable percentage shortages, the adverse economic effects of the petroleum shortage are substantially greater than those of an aluminum shortage. For example, at 5 percent shortages, GNP reduction is approximately twice as great for petroleum as for aluminum. At a 10 percent shortage, GNP reduction is approximately three times as much for a petroleum as for an aluminum shortage.
- Whereas the adverse effects of the petroleum shortage accelerate gradually as the shortage increases, very rapid

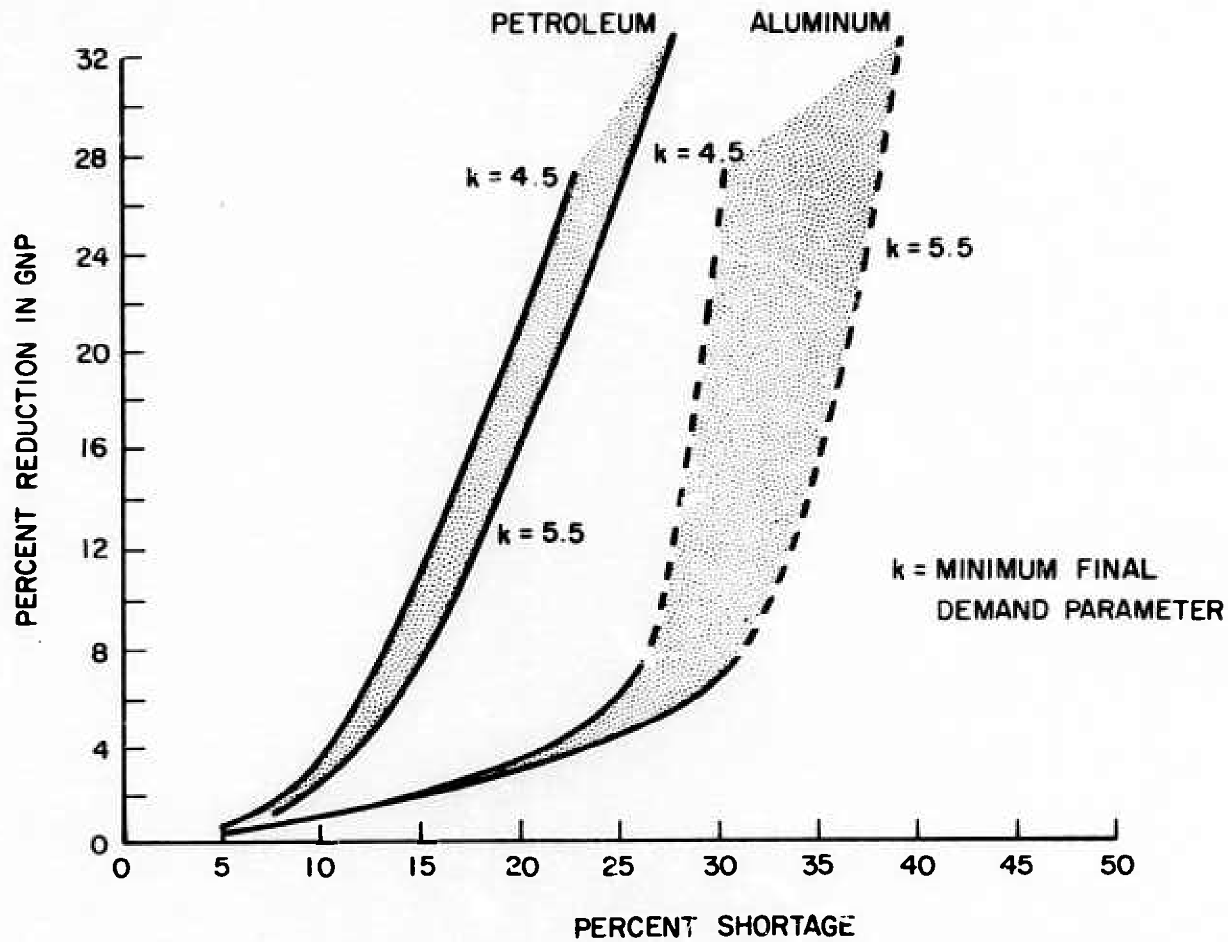

FIGURE IV-6. REDUCTION IN GNP FOR PETROLEUM AND ALUMINUM SHORTAGES

acceleration of economic disruption occurs at a shortage of aluminum of between 25 and 30 percent.

The general conclusion to be drawn from these observations is that the economy can sustain only relatively small deficits in petroleum availability but that there exists some buffer against the aluminum deficit. Analysis of the results suggests that the different nature of the economic responses to the petroleum and aluminum shortages is due to the ubiquity of the industrial demand for petroleum and the more limited number of industries that require aluminum. Thus, for an aluminum shortage, economic activity would be impaired but not crippled until the shortage became so great as to reduce substantially the output of key industries, whose output is required to support industrial activity in other sectors of the economy. As noted later, the appearance of rapidly increasing disruption of economic activity after an initial "threshold" period appears to be common for material resource shortages, whereas a much smaller "threshold" effect is observed for energy resource shortages.

An important limitation in the interpretation of GNP reduction due to an aluminum shortage is that at shortages greater than the apparent "threshold," the rate of economic deterioration predicted by the model calculation is extremely high. Such a period of economic dislocation is not likely to occur, as substitutes for aluminum--even if higher-priced and less desirable--will be used wherever possible in manufacturing products.* Because substitution possibilities are not included in this formulation of the model, the economic impacts at high aluminum shortages calculated by the model are not considered realistic. For this reason GNP reduction at large shortages of aluminum are shown in dotted lines in Figure IV-6. The model for the nonenergy resource shortages is thus useful for indicating: (1) relative economic impacts of different resource shortages before "threshold" impacts (i.e., before the onset of rapidly accelerated adverse impacts on GNP) bring about otherwise noneconomic

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*The large decline in GNP due to a petroleum shortage is probably unavoidable, because of the limited availability of energy substitutes.

substitution processes and (2) the approximate magnitude of the shortage of different materials that cause the rapid decline in economic activity.

4. Reducing Final Demand during an Aluminum Shortage

Table IV-3 shows the industries whose final demands have the highest shadow prices during an aluminum shortage. The interpretation developed earlier suggests that the manufacture of the products of these industries for final demand is most likely to be reduced by either market forces or government policy, in the absence of pressing societal needs for the products. Figure IV-7 compares DoD and civilian demand for the products of those industries with the highest shadow prices. The conclusion relevant to DoD planning is that in the event of an aluminum shortage, DoD is most likely to be affected by reductions in output of ordnance and aircraft. Thus, the analysis has indicated the specific shortages most likely to be of special concern to the DoD during a period of reduced availability of aluminum.

5. Simultaneous Shortages of Aluminum and Petroleum

The model is capable of simulating the effect of a combination of shortages occurring simultaneously. Figure IV-8 compares the cumulative effect of separate 10 percent aluminum and 7.5 percent petroleum shortages with the effect of a simultaneous 10 percent aluminum and 7.5 percent petroleum shortage. Whereas the effect of the two shortages occurring separately is a 2.9 percent reduction in GNP, the effect of the combined shortage is a 2.1 percent reduction in GNP. This result may be understood by noting that a shortage of one resource causes industrial output to decline. This reduction in output diminishes demand for other resources. Thus, the combined economic effects of simultaneous shortages are generally less than the sum of the economic effects of the shortages occurring separately.

6. Shortages of Other Material and Energy Resources

In Figure IV-9 are shown the effects of 12 energy and material shortages on GNP, as a function of the percent shortage of the resource.

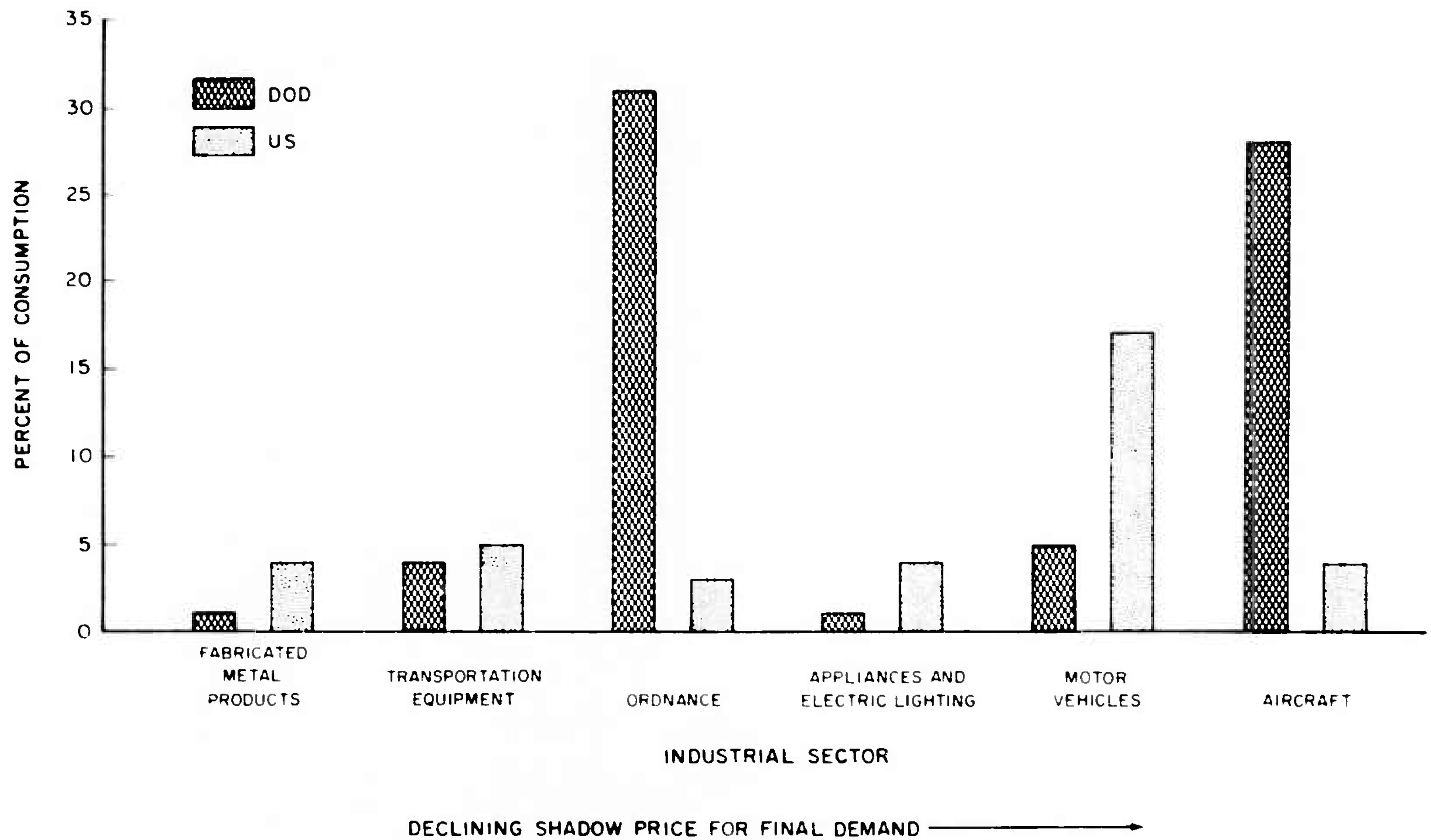

FIGURE IV-7. DOD AND U.S. ALUMINUM USE THROUGH CONSUMPTION OF PRODUCTS WITH HIGH FINAL DEMAND SHADOW PRICES DURING A SHORTAGE OF ALUMINUM

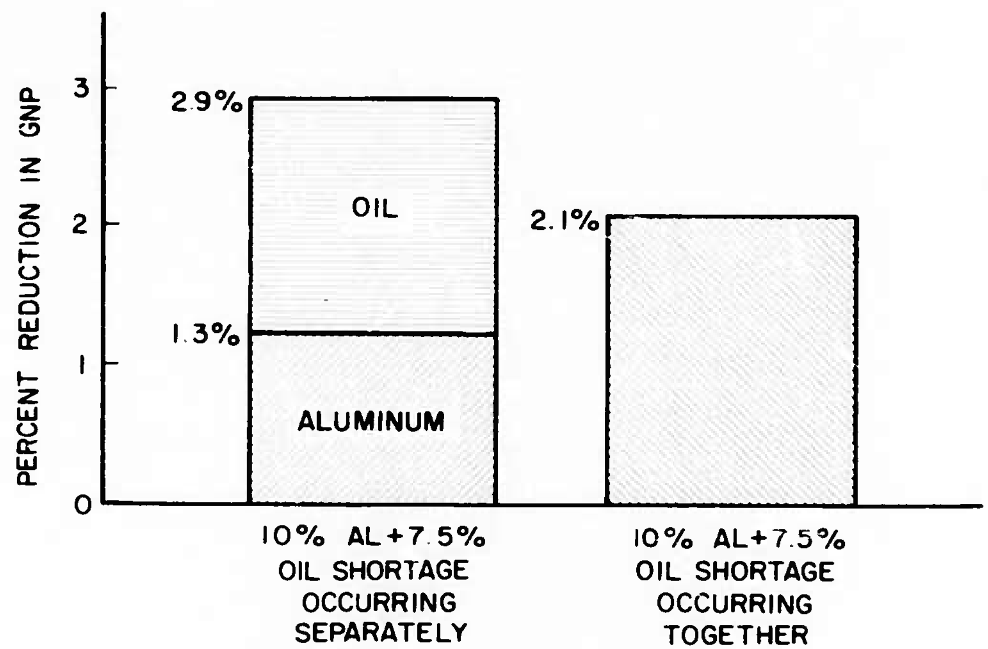

FIGURE IV-8. EFFECTS OF SIMULTANEOUS ALUMINUM AND OIL SHORTAGES

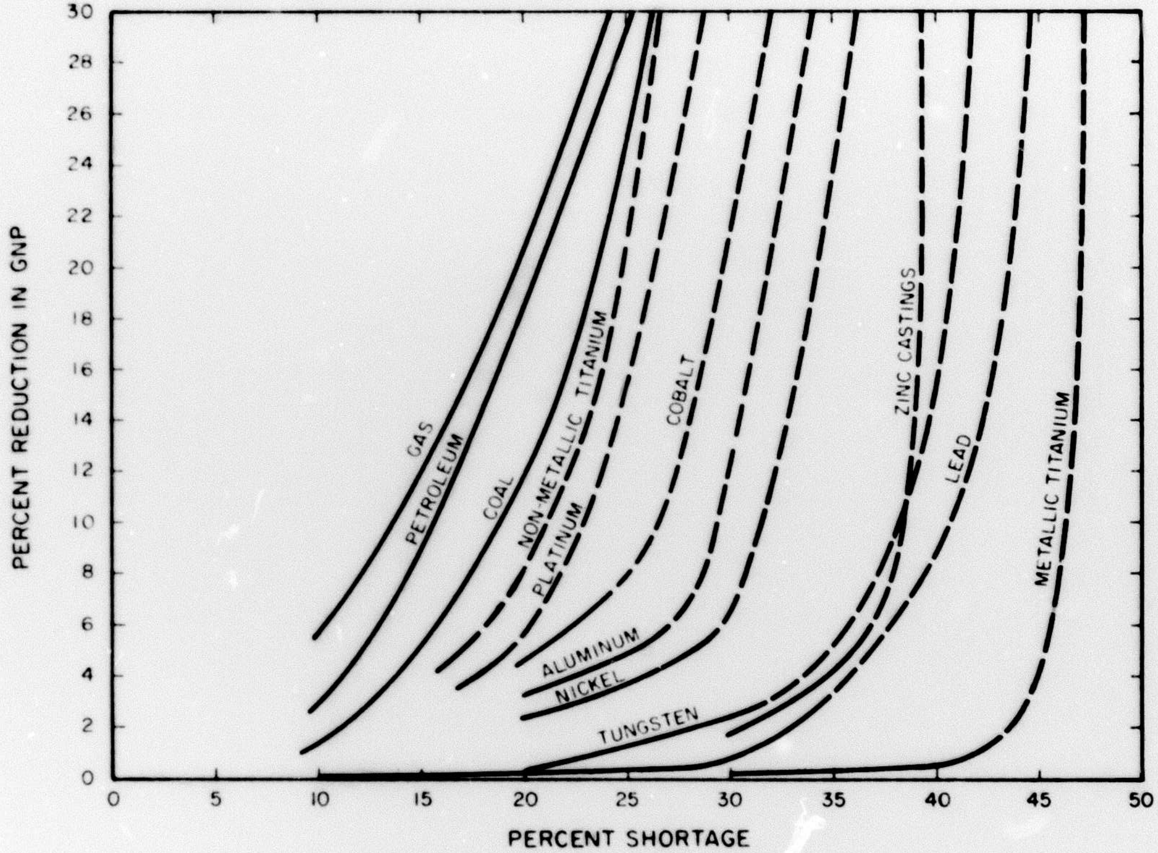

FIGURE IV-9. EFFECTS OF ENERGY AND MATERIAL SHORTAGES ON GNP

For clarity, we have omitted results of several of the material shortage calculations from the figure. Tin and chromium fall on the figure between the curves for cobalt and aluminum. Copper and silver fall between the aluminum and nickel curves. As for the aluminum calculation, we have plotted the percent reduction of GNP as a dotted line for material shortages that have a severe impact on the economy, since we assume that substitution would probably take place to avert the most adverse of the economic impacts.

Several observations are appropriately made from the results:

- Economic impacts vary significantly for shortages of different resources.
- Shortages of the energy resources have the greatest impact.
- Large effects on GNP occur between a 5 and 10 percent shortage for the energy resources.
- Non-metallic titanium, platinum, cobalt, tin, chromium, aluminum, and copper begin having strongly adverse effects on the economy at about a 15 percent shortage for the first two materials on the list and at between 20 and 25 percent shortage for the other materials.
- The remaining materials--silver, nickel, zinc castings, tungsten, lead and metallic titanium--exert a strongly adverse effect on GNP at a shortage of 30 percent or greater.

The results in Figure IV-9 may be used to establish a rank ordering of shortage impacts of different resources. Of the material resources with the greatest potential for causing large and adverse economic impacts, tin, chromium, and aluminum are largely imported and U.S. reserves of the raw materials are limited. The largest foreign sources of materials are: tin--Malaysia, Thailand and Bolivia; chromium--U.S.S.R., South Africa, and Rhodesia; bauxite--Jamaica, Surinam, and Australia. In view of the potential economic impacts of shortages of these three

materials and the large U.S. dependence on foreign sources that may be insecure, careful consideration should be given to the adequacy of our stockpile and the economic benefits that could accure from a stockpile for tin, chromium, and aluminum. Also, the benefits and costs of economic stockpile of platinum may merit analysis, since the economic impacts of a shortage can be substantial, about 60 percent of the platinum is imported, and the major foreign sources of platinum are the U.S.S.R. and South Africa. However, significant domestic platinum deposits exist and could be exploited.

A second important observation regarding the results in Figure IV-9 concerns their relevance to DoD planning for shortages. The analysis done for aluminum and petroleum, which relates DoD consumption patterns and high final demand shadow prices to specific industrial products that are most likely to be in short supply to DoD during a shortage, is equally applicable to the remaining resources. The relevant consumption and shadow price information is presented in the appendix. These results can be used for DoD planning in a manner analogous to that presented in this report for petroleum and aluminum.

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Appendix

DETAILED INPUTS AND RESULTS

While many of the detailed inputs and results of this study are too voluminous to publish, certain key items have been selected for publication so as to enhance the direct usefulness of the study. The appendix is organized into two sections: one giving input data to the calculations performed, and the other providing results. Since the orgin of the input data and an explanation of how to interpret the results were covered fully in the main body of the report, little additional explanation is given in this appendix.

A. Input Data

The input data presented are those associated with the 150-sector input-output table derived from the 404-sector table as described in Section III of the report. This table with its derived coefficients is the basic input both for the material consumption calculations and, in an aggregated form, for the linear programming analysis of shortage effects. In the first three columns of Table A-1, the 150 sectors are defined in terms of the industry numbers assigned by the Bureau of Economic Analysis (BEA) and used in the 1967 input-output tables.[1] Note that sectors 8 and 9 have the same industry number as do sectors 10, 11, and 12--these are sectors that were used from the disaggregated 404-sector table obtained from Lawrence Berkeley Laboratories, in which coal, crude petroleum, gas, and many other mining sectors were disaggregated to a greater extent than is found in the 367-sector input-output table published by BEA.

Column 4 of Table A-1 shows the deflation factors used to convert the 1972 final demand obtained from the Office of Preparedness[2] in 1963 dollars to 1967 dollars for use with the 1967 input-output table. Columns 5 and 6 give the U.S. and DoD final demands in millions of dollars. The final demand figures are given in 1967 dollars, i.e., after multiplication by

Table A-1

DEFINITION OF 1972 INPUT-OUTPUT SECTORS AND INPUTS

Sector Number	Sector Name	1967 Input-Output Industry No.	Deflation Factor	U.S. 1972 Final Demand ($ millions)	DoD 1972 Final Demand ($ millions)	Minimum Final Demand Factor (Percent)	Maximum Gross Output Factor (Percent)
1	Livestock	1.01- 1.03	1.139	$ 2,556.87	$ 2.28	40.79	100.00
2	Other Agriculture	2.01- 2.07	.991	7,843.59	2.97	24.85	100.00
3	Forestry and Fishery Products	3.00	1.438	496.22	1.44	0.00	100.00
4	Agric. Forest. and Fish Products	4.00	.811	34.96	16.26	0.00	100.00
5	Iron and Ferroalloy Ores Mining	5.00	.970	35.88	0.00	0.00	120.01
6	Copper Ore Mining	6.01	1.240	9.92	0.00	0.00	120.01
7	Nonferrous Metal Ores Mining	6.02	1.073	215.65	0.00	0.00	120.01
8	Anthracite Coal	7.00	1.047	73.67	3.95	29.87	112.80
9	Bituminous Coal	7.00	1.047	571.53	30.61	29.87	112.80
10	Crude Petroleum	8.00	1.017	8.08	0.00	0.00	105.96
11	Material Gas	8.00	1.017	3.68	0.00	0.00	105.96
12	Natural Gas Liquids	8.00	1.017	1.46	0.00	0.00	105.96
13	Stone and Clay Mining and Quarry	9.00	1.040	23.93	0.00	0.00	127.63
14	Chem. and Fertiliz. Mineral Mining	10.00	1.066	173.71	0.00	28.23	127.63
15	New Construction	11.01-11.05	1.126	93,053.26	977.49	75.75	111.92
16	Maint. and Rep. Const. Resid. Bldg.	12.01	1.142	237.52	99.35	49.14	111.92
17	Main. and Repair Const., all Others	12.02	1.142	2,795.46	1,056.30	49.14	111.92
18	Complete Guided Missiles	13.01	1.079	3,716.41	2,352.43	0.00	100.00
19	Tank and Tank Components	13.03	1.079	702.492	492.07	0.00	100.00
20	Ammun. Inc. for Small Arms	13.02	1.079	1,737.35	1,202.11	0.00	100.00
21	Other Ordnance	13.04-13.05	1.079	825.51	435.96	0.00	100.00
22	Alcoholic Beverages	14.21	1.074	8,675.30	2.15	93.41	102.85
23	Processed Foods ex. Alcohol	14.01-14.20	1.074	64,161.96	160.04	93.41	102.85
24	Tobacco Manufacturers	15.01-15.02	1.086	6,673.86	0.00	81.74	122.32
25	Broad and Narrow Fabric Yarn	16.01-16.04	1.019	1,538.32	39.73	28.64	106.64
26	Misc. Textile Goods and Floor Cov.	17.01-17.10	.952	1,967.78	13.33	76.22	106.64
27	Apparel	18.01-18.04	1.048	23,129.03	54.49	88.62	110.41
28	Misc. Fabric Textile Products	19.01-19.03	1.019	3,072.59	72.36	74.50	110.41
29	Lumb. and Wood Products ex. Containers	20.01-20.09	1.067	1,244.30	6.40	9.45	102.33
30	Wooden Containers	21.00	1.031	13.40	5.15	44.21	102.33
31	Household Furniture	22.01.22.04	1.081	5,072.91	8.65	79.02	110.04
32	Other Furniture and Fixtures	23.01-23.06	1.068	2,585.06	20.29	77.91	110.04
33	Pulp Paper and Paper Bd. Mills	24.01-24.03	1.073	851.20	9.66	86.96	102.12
34	Paper Products ex. Contain. and Boxes	24.04-24.07	1.073	2,028.72	18.25	86.96	102.12
35	Paperboard Containers and Boxes	25.00	1.027	292.74	9.25	33.02	102.12
36	Printing and Publishing	26.01-26.08	1.055	6,751.73	246.94	80.76	112.80
37	Indust. Chem. ex. Alumina	27.01	1.021	2,778.95	282.90	69.13	103.07
38	Fertilizers and Agric. Chem.	27.02	1.031	530.92	2.06	69.13	103.07
39	Misc. Chem. Products	27.04	1.021	990.66	138.90	69.13	103.07
40	Plastics Materials and Resins	28.01	.952	655.71	19.99	75.02	103.07
41	Synth. Rubber	28.02	.952	191.29	2.86	75.02	103.07
42	Cellulose and Noncellulose Fibers	28.03-28.04	.963	234.67	14.44	75.02	103.07
43	Drugs	29.01	1.000	4,670.00	17.00	88.53	103.07
44	Cleaning Preparations	29.02	1.041	3,092.71	22.92	88.53	103.07
45	Toilet Preparations	29.03	1.041	2,671.88	0.00	88.53	103.07
46	Paints and Allied Products	30.00	1.047	99.56	2.10	0.00	103.07
47	Petroleum Refining	31.01	1.035	15,765.54	914.92	81.50	103.95
48	Paving and Asphalt Materials	31.02-31.03	1.035	33.02	1.92	81.50	103.95
49	Tires and Inner Tubes	32.01	1.037	2,906.54	55.00	68.23	106.72
50	Other Rubber and Misc. Plastics	32.02-32.04	.983	1,937.85	130.70	68.23	106.272

Table A-1 (Continued)

Sector Number	Sector Name	1967 Input-Output Industry No.	Deflation Factor	U.S. 1972 Final Demand ($ millions)	DoD 1972 Final Demand ($ millions)	Minimum Final Demand Factor (Percent)	Maximum Gross Output Factor (Percent)
51	Leather Tann and Indust. Leath. Prod.	33.00	1.109	173.10	1.11	21.38	122.40
52	Footwear and Other Leath. Prod.	34.01-34.03	1.109	4,864.44	3.33	89.07	122.40
53	Glass and Glass Products	35.01-35.02	1.050	836.24	9.46	0.00	107.53
54	Stone and Clay Products	36.01-36.22	1.032	874.28	8.26	52.00	107.53
55	Blast Furn. and Basic Steel Prod.	37.01	1.038	898.97	28.03	17.01	110.90
56	Iron and Steel Foundaries	37.02	1.089	101.28	3.27	17.01	110.90
57	Iron and Steel Forging	37.03	1.089	45.74	0.00	17.01	110.90
58	Primary Iron and Steel Prod. Nec.	37.04	1.089	14.16	0.00	17.01	110.90
59	Primary Copper	38.01	1.122	170.66	1.12	49.41	110.90
60	Primary Zinc	38.03	1.196	26.31	-5.98	49.41	110.90
61	Primary Aluminum Inc. Alumina	38.04	.937	49.68	.93	49.41	110.90
62	Other Prime Nonferrous Metals Inc. Lead	38.02	1.196	7.18	-7.18	49.41	110.90
63	Second Nonferrous Metals	38.05	1.196	13.16	0.00	49.41	110.90
64	Copper Rolling and Drawing	38.06	1.338	54.89	0.00	49.41	110.90
65	Alum. Rolling and Drawing	38.07	.976	76.20	17.58	49.41	110.90
66	Other Nonferrous Rolling and Drawing	38.08	1.237	143.56	3.71	49.41	110.90
67	Nonferrous Wire Drawing and Insulating	38.09	1.237	232.66	60.64	49.41	110.90
68	Aluminum Castings	38.10	1.189	39.07	2.38	49.41	110.90
69	Brass Bronze and Copper Casting	38.11	1.189	22.61	16.66	49.41	110.90
70	Nonferrous Casting Nec.	38.12	1.189	4.76	0.00	49.41	110.90
71	Nonferrous Forging	38.13	1.189	19.04	2.38	49.41	110.90
72	Metal Containers	39.01-39.02	1.068	49.16	6.41	0.00	111.45
73	Heat and Plumb. Prod. ex. Electricity	40.01-40.03	1.011	263.96	3.09	55.82	111.45
74	Fab. Struc. Sheet. and Other Met. Prod.	40.04-40.09	1.062	1,433.75	22.31	55.82	111.45
75	Screw Machine Products	41.01	1.109	136.45	14.42	59.92	111.45
76	Metal Stamp Inc. Automobiles	41.02	1.109	868.64	12.20	59.92	111.45
77	Other Fabricated Metal Prod.	42.01-42.11	1.092	2,259.09	20.77	58.70	111.45
78	Engines and Turbines	43.01-43.02	1.078	2,098.50	147.81	42.90	118.24
79	Farm Machinery	44.00	1.094	4,147.60	12.04	28.28	118.24
80	Constr. Min. and Oil Field Machinery	45.01-45.03	1.108	5,004.12	136.33	57.92	118.24
81	Materials Handl. Machinery and Equip.	46.01-46.04	1.075	1,295.30	109.74	61.32	118.24
82	Metal Work Machinery and Equip.	47.01-47.04	1.144	3,161.18	82.41	61.19	118.24
83	Special Indus. Machinery and Equip.	48.01-48.06	1.117	3,852.15	15.65	62.38	118.24
84	Pumps and Compressors	49.01	1.079	1,289.29	12.96	63.61	118.24
85	Ball and Roller Bearings	49.02	1.079	152.25	11.88	63.61	118.24
86	Fans, Furn. and Other Genl. Indus. Machin.	49.03-49.07	1.079	1,688.82	68.03	63.61	118.24
87	Machine Shop Products	50.00	1.089	240.78	53.38	0.00	118.24
88	Computing and Related Machines	51.01	1.011	4,24.25	227.66	39.35	118.24
89	Typewriters and Other Off. Machin. Nec	51.02-51.04	1.083	1,648.35	16.25	39.35	118.24
90	Refrig. Machinery	52.03	.985	2,197.02	38.44	75.50	118.24
91	Other Service, Indus. Machines	52.01-52.02 52.04-52.05	.985	1,582.96	11.83	75.50	118.24
92	Elec. Meas. Instr.	53.01	1.104	1,001.89	132.55	6.47	113.15
93	Transf. Switchgr and Board Appar.	53.02-53.03	1.104	1,337.89	54.13	6.47	113.15
94	Motors Control and Elec. Prod. Nec.	53.04-53.08	1.012	1,389.37	153.92	6.47	113.15
95	Household Appliances	54.01-54.07	.982	6,216.98	8.84	80.96	113.15
96	Elec. Lighting and Wiring Equip.	55.01-55.03	1.065	1,223.58	18.12	81.38	113.15
97	Radio and TV Receiving Sets	56.01	.949	5,092.68	37.93	35.07	113.15
98	Phonograph Records	56.02	.949	473.142	1.90	35.07	113.15
99	Telephone and Telegraph Apparatus	56.03	1.006	1,443.92	109.68	35.07	113.15
100	Radio and TV Communication Equip.	56.04	1.016	5,799.47	3,075.32	35.07	113.15

Table A-1 (Concluded)

Sector Number	Sector Name	1967 Input-Output Industry No.	Deflation Factor	U.S. 1972 Final Demand ($ millions)	DoD 1972 Final Demand ($ millions)	Minimum Final Demand Factor (Percent)	Maximum Gross Output Factor (Percent)
101	Electron. Compon. and Access.	57.01-57.03	.858	1,293.88	259.98	5.37	113.15
102	Engine Elec. Equip.	58.04	1.095	380.14	48.20	76.12	113.15
103	Batt. X-ray and Other Elec. Equip.	58.01-58.03 58.05	1.095	1,306.95	53.68	76.12	113.15
104	Truck and Bus Bodies and Truck Trail.	59.01-59.02	1.033	2,087.51	51.70	72.84	112.80
105	Motor Vehicles and Parts	59.03	1.033	47,890.70	770.28	72.84	112.80
106	Aircraft-Complete	60.01	1.090	5,783.38	2,370.73	59.78	156.43
107	Aircraft Engn. and Prt. Inc. for Miss.	60.02	1.090	3,042.79	1,805.60	59.78	156.43
108	Aircraft Equip. and Parts Nec.	60.03-60.04	1.090	2,832.23	1,502.30	59.78	156.43
109	Ship Bldg. and Repairing	61.01-61.02	1.082	1,876.00	858.43	62.40	156.43
110	Locom. RR Streetcars and Parts	61.03-61.04	1.021	2,170.52	4.09	62.40	156.43
112	Trailer Coaches	61.06	1.056	1,356.28	0.00	62.40	156.43
112	Other Transportation Equip. Nec.	61.05;61.07	1.038	1,605.97	24.92	62.40	156.43
113	Sci. Instrum. Meas. and Controls	62.01-62.03	1.080	2,315.56	223.67	45.94	114.09
114	Surg. Dent. Med. Supplies and Equip.	62.04-62.06	1.074	1,382.24	35.44	45.94	114.09
115	Watches, Clocks and Parts	62.07	1.080	638.59	1.08	45.94	114.09
116	Optic Opthal. Goods inc. Lenses	63.01-63.02	1.023	819.12	18.43	46.48	114.09
117	Photo Equip. and Supplies	63.03	1.096	2,248.82	117.38	46.48	114.09
118	Misc. Manufacturing	64.01-64.12	1.058	9,219.23	9.53	75.05	105.01
119	Railroads and Related Services	65.01	.965	4,693.75	139.05	70.49	109.83
120	Motor Frgt. Transp. and Warehsng.	65.03	1.137	6,669.37	475.98	70.49	107.32
121	Water Transportation	65.04	.935	3,451.58	247.81	70.49	100.00
122	Air Transportation	65.05	.886	3,206.31	300.51	70.49	132.40
123	Pipeline Transportation	65.06	1.048	412.86	2.51	70.49	100.00
124	Local Pass. and Other Transp.	65.02	1.048	4,248.49	25.80	70.49	100.00
125	Communications ex. Radio and TV	65.07	.970	12,799.85	345.60	79.59	100.00
126	Radio and TV Broadcasting	66.00	1.161	119.65	--	0.00	100.00
127	Electric Utilities	67.00	.991	12,757.43	137.77	77.59	102.43
128	Gas Utilities	68.01	.993	5,473.24	41.74	77.59	105.99
129	Water and Sanitary Services	68.02	..097	2,105.98	18.66	77.59	100.00
130	Wholesale and Retail Trade	68.03	1.051	40,334.68	619.39	89.12	100.00
131	Retail Trade	69.01	1.119	108,161.64	-20.46	89.12	100.00
132	Finance and Insurance	69.02	1.192	30,976.31	19.09	81.07	113.98
133	Owner Occupied Dwellings	70.01-70.05	1.054	60,248.13	75.91	83.60	102.73
134	Real Estate	71.01	.986	27,120.49	0.00	83.60	102.73
135	Hotels and Lodging Places	71.02	1.124	4,547.91	301.47	86.42	146.04
136	Persl and Repair Services ex. Auto.	72.01	1.116	13,036.18	1.12	86.42	146.04
137	Advertising	72.02-72.03	1.119	139.97	2.24	61.29	113.98
138	Misc. Busn. Services ex. Advertsg.	73.02	1.160	11,509.28	1,732.37	61.29	113.96
139	Auto Repair and Services	75.00	1.088	9,787.10	20.69	66.02	100.00
140	Amusements	76.01-76.02	1.210	7,698.93	158.55	83.70	100.00
141	Med. and Educ. Servs.--Nonprof. Org.	77.01-77.05	1.256	62,269.58	829.31	63.13	100.00
142	Fed. Govt. Enterprises	78.01-78.04	1.072	2,168.06	111.57	79.10	100.00
143	State and Local Govt.	79.01-79.03	1.058	1,251.66	15.88	67.44	100.00
144	Imports	80.01-80.02	1.000	- 31,868.72	-1,037.80	169.63	100.00
145	Business Trav. Entertain. and Gifts	81.00	1.000	--	--	131.78	100.00
146	Office Supplies	82.00	1.000	876.00	89.00	43.90	100.00
147	Scrap Used	83.00	1.000	229.00	-206.00	0.00	100.00
148	Govt. Compensation	84.00	1.000	74,577.00	19,786.00	34.28	100.00
149	Rest of the World Industry	85.00	1.000	7,926.00	--	46.88	100.00
150	Household Industry	86.00	1.000	3,034.00	--	51.94	100.00

the deflation factor. Column 7 is the factor by which the U.S. final demand was multiplied to obtain the minimum final demand used in the linear program calculation. These factors correspond to that case described in the report as 5 standard deviations below the least squares regression line fit to the historical final demand data. The last column shows the factor by which the 1972 gross output for each sector was multiplied to obtain the maximum capacity constraints (i.e., maximum gross output) used in the linear program calculation.

Table A-2 defines the 37 sectors used in the linear programming calculations in terms of the 150 sectors defined in Table A-1. The goal in defining these sectors was to leave the energy sectors disaggregated but to aggregate other sectors whose products were similar.

B. Results

Examples of each of the types of results obtained are given in the main body of the report. The purpose of this section of the appendix is to present the complete set of results for all materials studied.

1. Sample Computer Output for Material Consumption Estimates

Table A-3 is the computer output for DoD consumption of aluminum. The first two columns define the sector, the third gives U.S. consumption by that industry in units of thousands of tons. Total sales in millions of dollars is shown in the fourth column. Column 5 shows the consumption factor, which is the ratio of U.S. consumption divided by total sales for each sector. DoD final demand is shown in column 6 in millions of 1967 dollars. Column 7 shows the direct consumption for that sector in units of thousands of tons. The direct consumption, as described previously, is the material used by an industry to produce its DoD final demand. Column 8 is the material consumed by an industry to manufacture products sold to other industries (including that consumed by itself) to support their production for DoD final demand. Column 9 is the sum of columns 7 and 8 and is thus the total material consumed by an industry to support all of DoD final demands. Column 10 is the material consumed by other industries to provide the products purchased by an industry (including

Table A-2

DEFINITION OF THE 37-SECTOR AGGREGATION

Sector Number	Sector Name	150-Sector Components
1	Agriculture	1-4
2	Mining	5-7,13,14
3	Anthracite coal	8
4	Bituminous coal	9
5	Crude petroleum	10
6	Natural gas	11
7	Natural gas liquids	12
8	Construction	15-17
9	Ordnance	18-21
10	Food processing and tobacco	22-24
11	Textiles, wood and paper products	25-36
12	Chemical products	37-39
13	Plastic, rubber and cellulose	40-45
14	Paints and allied products	46
15	Petroleum refining	47
16	Paving and asphalt materials	48
17	Rubber, leather, glass and clay	49-54
18	Primary and secondary metal products	55-71
19	Fabricated metal products	72-77
20	Engines and industrial machinery	78-83
21	Machine shop products	84-87
22	Computers, office and other service machinery	88-92
23	Appliances and electric lighting	93-96
24	Communication and electrical equipment	97-103
25	Motor vehicles	104,105
26	Aircraft	106-108
27	Other transportation equipment	109-112
28	Instruments and miscellaneous	113-118

Table 2 (concluded)

Sector Number	Sector Name	150-Sector Components
29	Transportation and communication services	119-122, 125,126, 129
30	Pipeline transportation	123
31	Local passenger and other transportation	124
32	Electric utilities	127
33	Gas utilities	128
34	Trade, real estate and services	130-141
35	Government enterprises	142,143
36	Imports	144
37	Dummy and special industries	145-150

Table A-3

DOD CONSUMPTION OF ALUMINUM (DIRECT AND INDIRECT) FOR 1972

(Thousand Short Tons)

		US CONS	TOTAL US SALES	CONS. FACTOR	FINAL DEMAND	CONSUMPTION DIRECT	INDUSTRIAL SECTOR INDIRECT	INDUSTRIAL SECTOR TOTAL	FINAL DEMAND SECTOR INDIRECT	FINAL DEMAND SECTOR TOTAL
1	LIVESTOCK	0	34673.59	0.00000	2.278	0.000	0.000	0.000	.004	.004
2	OTHER AGRICULTURE	0	32687.96	0.00000	2.974	0.000	0.000	0.000	.004	.004
3	FORESTRY AND FISHERY PRODUCTS	0	2520.49	0.00000	1.435	0.000	0.000	0.000	.006	.006
4	AGRIC FOREST & FISH SERVICES	0	2888.67	0.00000	16.259	0.000	0.000	0.000	.019	.019
8	ANTHRACITE COAL	0	187.99	0.00000	3.946	0.000	0.000	0.000	.008	.008
9	BITUMINOUS COAL	0	3585.08	0.00000	30.618	0.000	0.000	0.000	.051	.051
15	NEW CONSTRUCTION	460	93053.26	.00494	977.493	4.829	0.000	4.829	12.504	17.334
16	MAINT & REP. CONST RESID BLDG	16	7458.92	.00211	99.348	.209	.132	.341	.755	.964
17	MAIN. & REPAIR CONST. ALL OTHE	35	16884.93	.00211	1056.290	2.224	.804	3.028	7.084	9.307
18	COMPLETE GUIDED MISSLES	5	4315.64	.03119	2352.429	2.791	.329	3.120	13.219	16.010
19	TANK & TANK COMPONENTS	17	847.13	.01965	492.068	9.671	1.101	10.772	5.732	15.403
20	AMMUN. INC FOR SMALL ARMS	113	2274.80	.04983	1202.113	59.905	12.810	72.714	15.947	75.851
21	OTHER ORDNANCE & ACCESSORIES	4	1155.47	.00306	435.955	1.336	.249	1.584	3.817	5.153
22	ALCOHOLIC BEVERAGES	0	12781.19	0.00000	2.148	0.000	0.000	0.000	.025	.025
23	PROCESSED FOODS EX ALCOHOL	0	94795.67	0.00000	160.037	0.000	0.000	0.000	.751	.751
25	BROAD & NARROW FABRICS YARN	0	21611.20	0.00000	39.732	0.000	0.000	0.000	.039	.039
26	MISC TEXTILE GOODS & FLOOR COV	0	5921.66	0.00000	13.326	0.000	0.000	0.000	.017	.017
27	APPAREL	0	32824.45	0.00000	54.485	0.000	0.000	0.000	.046	.046
28	MISC FABRIC TEXTILE PRODUCTS	0	5722.76	0.00000	72.356	0.000	0.000	0.000	.106	.106
29	LUMB & WOOD PROD EX CONTAINERS	10	16065.53	.00059	6.403	.004	.183	.186	.015	.019
30	WOODEN CONTAINERS	0	628.04	0.00000	5.154	0.000	0.000	0.000	.011	.011
31	HOUSEHOLD FURNITURE	99	6442.28	.01538	8.646	.133	.293	.426	.036	.169
32	OTHER FURNITURE AND FIXTURES	31	3347.14	.00908	20.288	.184	.284	.467	.106	.289
33	PULP PAPER & PAPERBD MILLS	0	12880.33	0.00000	9.661	0.000	0.000	0.000	.020	.020
34	PAPER PROD. EX CONTAIN & BOXES	0	8214.13	0.00000	18.246	0.000	0.000	0.000	.033	.033
35	PAPERBOARD CONTAINERS & BOXES	36	7299.77	.00493	9.245	.046	.748	.794	.027	.072
36	PRINTING AND PUBLISHING	0	28204.40	0.00000	246.937	0.000	0.000	0.000	.559	.559
37	INDUS CHEM EX ALUMINA	0	19750.23	0.00000	282.909	0.000	0.000	0.000	.796	.796
38	FERTILIZERS & AGRIC CHEM	0	3270.56	0.00000	2.062	0.000	0.000	0.000	.012	.012
39	MISC CHEM PRODUCTS	0	4257.14	0.00000	138.897	0.000	0.000	0.000	.562	.562
40	PLASTICS MATERIALS & RESINS	0	5387.23	0.00000	19.905	0.000	0.000	0.000	.047	.047
41	SYNTH RUBBER	0	1477.35	0.00000	2.655	0.000	0.000	0.000	.005	.005
42	CELLULOS & NONCELLULOS FIBERS	0	4281.57	0.00000	14.441	0.000	0.000	0.000	.021	.021
43	DRUGS	0	7488.39	0.00000	17.000	0.000	0.000	0.000	.032	.032
44	CLEANING PREPARATIONS	0	4989.50	0.00000	22.917	0.000	0.000	0.000	.159	.159
45	PAINTS AND ALLIED PRODUCTS	0	2349.57	0.00000	2.096	0.000	0.000	0.000	.023	.023
47	PETROLEUM REFINING	0	31923.18	0.00000	914.918	0.000	0.000	0.000	1.486	1.486
48	PAVING & ASPHALT MATERIALS	0	1330.50	0.00000	1.916	0.000	0.000	0.000	.004	.004
49	TIRES & INNER TUBES	0	5993.68	0.00000	55.002	0.000	0.000	0.000	.078	.078
50	OTHER RUBBER & MISC PLASTICS	0	12319.55	0.00000	138.699	0.000	0.000	0.000	.337	.337
51	LEATH TANN & INDUST LEATH PROD	0	1546.31	0.00000	1.110	0.000	0.000	0.000	.002	.002
52	FOOTWEAR & OTHER LEATH PROD	0	5494.59	0.00000	3.229	0.000	0.000	0.000	.006	.006
53	GLASS AND GLASS PRODUCTS	0	4832.15	0.00000	9.455	0.000	0.000	0.000	.014	.014
54	STONE AND CLAY PRODUCTS	0	13352.78	0.00000	8.258	0.000	0.000	0.000	.015	.015
55	BLAST FURN & BASIC STEEL PROD	73	30076.69	.00243	28.028	.068	3.185	3.253	.091	.159
56	IRON & STEEL FOUNDRIES	14	5970.66	.00230	3.267	.008	.663	.671	.014	.022
57	IRON & STEEL FORGINGS	3	2167.13	.00137	0.000	0.000	.225	.225	0.000	0.000
58	PRIMARY IRON & STEEL PROD NEC	5	737.31	.00665	0.000	0.000	.344	.344	0.000	0.000
59	PRIMARY COPPER	0	3154.92	0.00000	1.123	0.000	0.000	0.000	.003	.003
60	PRIMARY ZINC	0	583.47	0.00000	-5.980	0.000	0.000	0.000	-.012	-.012
61	PRIMARY ALUMINUM INC ALUMINA	0	2990.96	0.00000	.937	0.000	0.000	0.000	.002	.002
62	OTH PRIME NONFERR MET INC LEAD	0	2532.33	0.00000	-7.177	0.000	0.000	0.000	-.015	-.015
64	COPPER ROLLING & DRAWING	80	3074.16	.02602	0.000	0.000	4.091	4.091	0.000	0.000
65	ALUM ROLLING & DRAWING	0	3477.32	0.00000	17.584	0.000	0.000	0.000	.078	.078

Table A-3 (Continued)

		US CONS	TOTAL US SALES	CONS. FACTOR	FINAL DEMAND	CONSUMPTION: DIRECT	CONSUMPTION: INDUSTRIAL SECTOR INDIRECT	CONSUMPTION: INDUSTRIAL SECTOR TOTAL	CONSUMPTION: FINAL DEMAND SECTOR INDIRECT	CONSUMPTION: FINAL DEMAND SECTOR TOTAL
66	OTH NONFERR ROLLING • DRAWING	0	1312.99	0.00000	3.713	0.000	0.000	0.000	.013	.013
67	NONFERR WIRE DRAW • INSULATING	416	4524.66	.09194	60.640	5.575	14.435	20.010	.970	6.546
68	ALUM CASTINGS	0	1289.22	0.00000	2.380	0.000	0.000	0.000	.017	.017
69	BRASS BRONZE • COPPER CASTINGS	35	608.43	.05753	16.658	.958	1.566	2.025	.088	1.047
70	NONFERR CASTINGS NEC	36	795.30	.04464	0.000	0.000	2.466	2.466	0.000	0.000
71	NONFERR FORGINGS	0	538.83	0.00000	2.380	0.000	0.000	0.000	.024	.024
72	METAL CONTAINERS	574	3891.90	.14746	6.412	.946	7.553	8.498	.035	.980
73	HEAT • PLUMB PROD EX ELECTRIC	36	2369.99	.01498	3.093	.046	.730	.776	.039	.085
74	FAB STRUC SHEET • OTH MET PROD	906	12518.78	.07240	22.319	1.616	17.966	19.584	.239	1.855
75	SCREW MACHINE PRODUCTS	22	3326.69	.00655	14.422	.095	1.004	1.099	.076	.171
76	METAL STAMP INC AUTOMOBILES	284	8782.40	.03231	12.203	.394	9.569	9.963	.071	.465
77	OTHER FABRICATED METAL PROD	380	15188.46	.02500	20.766	.519	14.699	15.218	.135	.654
78	ENGINES • TURBINES	36	4543.17	.00797	147.612	1.176	1.239	2.417	1.124	2.302
79	FARM MACHINERY	23	5293.27	.00438	12.035	.053	.120	.173	.073	.126
80	CONSTR MIN • OILFIELD MACHINRY	14	7290.08	.00192	136.325	.262	.180	.442	.739	1.000
81	MATERIALS HANDL MACHIN • EQUIP	13	2647.01	.00485	109.735	.533	.220	.753	.946	1.476
82	METALWORK MACHIN • EQUIP	27	8438.46	.00316	82.406	.261	1.401	1.662	.470	.731
83	SPECIAL INDUS MACHIN • EQUIP	30	5719.19	.00524	15.650	.082	.251	.333	.103	.185
84	PUMPS • COMPRESSORS	7	2866.78	.00227	12.958	.029	.269	.298	.103	.132
85	BALL • ROLLER BEARINGS	1	1683.32	.00045	11.878	.005	.035	.040	.030	.036
86	FANS FURN • OTH GENL INDSTMACH	30	4297.27	.00698	68.028	.473	.854	1.327	.505	.978
87	MACHINE SHOP PRODUCTS	38	4390.44	.00856	53.384	.456	4.148	4.604	.218	.674
88	COMPUTING • RELATED MACHINES	6	5292.63	.00098	227.663	.222	.116	.339	1.566	1.788
89	TYPEWRITERS • OTH OFF MACH NEC	10	2105.31	.00492	16.245	.080	.063	.143	.055	.135
90	REFRIG MACHINERY	107	5065.55	.02107	38.440	.810	1.654	2.464	.523	1.333
91	OTH SERVICE INDUS MACHINES	11	1893.59	.00586	11.828	.069	.074	.143	.112	.181
92	ELEC MEAS INSTR	9	1418.40	.00652	132.554	.864	.482	1.347	.839	1.703
93	TRANSF SWITCHGR • BOARD APPAR	21	3059.72	.00672	54.126	.364	.599	.963	.538	.901
94	MOTORS CONTROL • ELEC PROD NEC	65	5821.38	.01111	153.924	1.709	2.496	4.205	1.430	3.140
95	HOUSEHOLD APPLIANCES	124	8505.71	.01460	8.841	.129	.789	.916	.093	.222
96	ELEC LIGHTING • WIRING EQUIP	125	5073.31	.02466	18.119	.447	3.291	3.738	.124	.571
97	RADIO • TV RECEIVING SETS	3	6068.58	.00054	37.927	.021	.033	.054	.281	.301
98	PHONOGRAPH RECORDS	0	501.81	0.00000	1.896	0.000	0.000	0.000	.003	.003
99	TELEPHONE • TELEGRAPH APPARAT	16	2442.89	.00637	109.678	.696	.569	1.266	.747	1.445
100	RADIO • TV COMMUNICATION EQUIP	38	7543.58	.00502	3075.321	15.451	2.563	18.013	17.666	33.117
101	ELECTRON COMPON • ACCESS	48	8502.54	.00562	259.978	1.462	6.494	7.955	1.650	3.111
102	ENGINE ELEC EQUIP	13	2128.81	.00604	48.203	.291	.494	.785	.502	.793
103	BATT XRAY • OTH ELEC EQUIP	7	2045.39	.00345	53.660	.185	.097	.282	.388	.573
104	TRUCK • BUS BODIES • TRK TRAIL	138	2762.32	.04963	51.697	2.576	.671	3.247	.491	3.067
105	MOTOR VEHIC • PARTS	520	72442.47	.00717	770.279	5.525	3.734	9.258	6.427	13.952
106	AIRCRAFT - COMPLETE	73	7634.84	.00957	2370.739	22.683	8.140	30.823	21.025	43.709
107	AIRCFT ENGN • PRT INC FOR MISS	32	5171.29	.00621	1805.602	11.208	5.039	16.247	10.302	21.510
108	AIRCRAFT EQUIP • PARTS NEC	62	6539.24	.01252	1502.304	18.815	18.360	37.175	12.985	31.800
109	SHIPBLDG • REPAIRING	20	2409.68	.00836	858.434	7.178	.312	7.490	7.632	14.811
110	LOCOM RR STREET CARS • PARTS	13	2976.88	.00448	4.066	.018	.156	.177	.028	.046
111	TRAILER COACHES	219	1385.95	.15801	0.000	0.000	.130	.130	0.000	0.000
112	OTHER TRANSPORTATION EQUIP NEC	7	1906.62	.00366	24.915	.086	.023	.109	.155	.241
113	SCI INSTRUM MEAS • CONTROLS	35	4523.62	.00779	223.668	1.743	1.683	3.426	1.529	3.272
114	SURG DENT MED SUPPLIES • EQUIP	2	2284.46	.00085	35.442	.030	.020	.050	.152	.182
115	WATCHES CLOCKS • PARTS	3	1162.60	.00262	1.081	.003	.106	.109	.005	.008
116	OPTIC OPTHAL GOODS INC LENSES	1	1169.93	.00085	18.430	.016	.029	.044	.052	.068
117	PHOTO EQUIP • SUPPLIES	12	4109.25	.00290	117.376	.351	.229	.580	.283	.634
118	MISC MANUFACTURING	45	13980.34	.00320	9.526	.030	.325	.355	.034	.065
119	RAILROADS • RELATED SERVICES	0	15570.58	0.00000	139.046	0.000	0.000	0.000	.228	.228
120	MOTOR FRGT TRANSP • WAREHSNG	0	21801.02	0.00000	475.977	0.000	0.000	0.000	.354	.354

Table A-3 (Concluded)

		US CONS	TOTAL US SALES	CONS. FACTOR	FINAL DEMAND	DIRECT	INDUSTRIAL SECTOR INDIRECT	INDUSTRIAL SECTOR TOTAL	FINAL DEMAND SECTOR INDIRECT	FINAL DEMAND SECTOR TOTAL
						---C O N S U M P T I O N---				
121	WATER TRANSPORTATION	0	7594.96	0.00000	247.811	0.000	0.000	0.000	.498	.498
122	AIR TRANSPORTATION	0	7960.48	0.00000	300.508	0.000	0.000	0.000	.394	.394
123	PIPELINE TRANSPORTATION	0	1467.16	0.00000	2.507	0.000	0.000	0.000	.004	.004
124	LOCAL PASS • OTHER TRANSP	0	6631.48	0.00000	25.795	0.000	0.000	0.000	.020	.020
125	COMMUNICATIONS EX RADIO • TV	0	23761.02	0.00000	345.601	0.000	0.000	0.000	.239	.239
126	ELEC UTILITIES	0	25694.14	0.00000	137.774	0.000	0.000	0.000	.142	.142
128	GAS UTILITIES	0	16367.36	0.00000	41.743	0.000	0.000	0.000	.033	.033
129	WATER • SANITARY SERVICES	0	4117.26	0.00000	18.656	0.000	0.000	0.000	.036	.036
130	WHOLESALE • RETAIL TRADE	0	75150.55	0.00000	619.385	0.000	0.000	0.000	.765	.765
131	RETAIL TRADE	0	123653.03	0.00000	-20.147	0.000	0.000	0.000	-.012	-.012
132	FINANCE • INSURANCE	0	57600.02	0.00000	19.087	0.000	0.000	0.000	.010	.010
133	OWNER OCCUPIED DWELLINGS	0	60248.12	0.00000	75.914	0.000	0.000	0.000	.052	.052
135	HOTELS • LODGING PLACES	0	6778.52	0.00000	301.469	0.000	0.000	0.000	.333	.333
136	PSNL • REPAIR SERVICES EX AUTO	0	16322.10	0.00000	1.116	0.000	0.000	0.000	.002	.002
137	ADVERTISING	0	20219.26	0.00000	2.240	0.000	0.000	0.000	.004	.004
138	MISC BUSN SERVCS EX ADVERTSG	0	48717.73	0.00000	1732.368	0.000	0.000	0.000	2.462	2.462
139	AUTO REPAIR • SERVICES	0	17795.46	0.00000	20.685	0.000	0.000	0.000	.115	.115
140	AMUSEMENTS	0	12154.51	0.00000	158.529	0.000	0.000	0.000	.113	.113
141	MED • EDUC SRVS - NONPRF ORG	0	65666.26	0.00000	829.306	0.000	0.000	0.000	.590	.590
142	FED GOVT ENTERPRISES	0	9370.59	0.00000	111.568	0.000	0.000	0.000	.076	.076
143	STATE • LOCAL GOVT ENTERPRISES	0	11454.84	0.00000	15.884	0.000	0.000	0.000	.033	.033
144	IMPORTS	0	0.00	0.00000	-1037.800	0.000	0.000	0.000	0.000	0.000
146	OFFICE SUPPLIES	0	3439.13	0.00000	89.000	0.000	0.000	0.000	.276	.276
147	SCRAP USED • SECONDHAND GOODS	0	3442.58	0.00000	-206.000	0.000	0.000	0.000	-2.840	-2.840
148	GOVT COMPENSATION	0	74577.00	0.00000	19786.000	0.000	0.000	0.000	0.000	0.000
	TOTALS	5709	1822126.79	.00313	46[illegible]04.724	187.954	164.461	352.416	164.461	352.416
	EST. UNASSIGNED MATERIAL	0						0.000		0.000
	GRAND TOTAL	5709						352.416		352.416
	PERCENT OF US CONSUMPTION IS	6.17								

those purchased from itself) to support its production for DoD final demand. Finally, column 11 is the total of columns 7 and 10 and is the total material consumed by all industries to produce that final demand product.

Table A-4 is an example of the detail that is available to extend the material flow information in Table A-3. The example shown is a disaggregation of material flows for sector 101--electronic components and accessories. Column 9 shows aluminum consumption to produce goods sold by sector 101 to the other sectors. Column 11 shows aluminum consumption by sectors to produce goods sold to sector 101. For example, column 9 indicates that the electronics components sector consumes 3.851 thousand tons of aluminum to produce the goods it sells to the radio and TV communication equipment sector, 100. It also consumes .381 thousand tons to produce goods it sells to sector 106, complete aircraft. In column 11, the table shows that sector 67, nonferrous wire drawing and insulating, consumes .457 thousand tons of aluminum to produce goods it sells to sector 101 to support its production for final demand. The self-consumption can be obtained from this table by subtracting the direct consumption, 1,462, from the total consumption of sector 101, 1.764, shown in both columns 9 and 11, to give .302.

A computer printout similar to Table A-3 for all materials studied is available, as is the full backup of Table A-4 for each sector for each material.

2. Material Flow Diagrams

Figures A-1 through A-34 are the material consumption diagrams for the 17 materials analyzed for both U.S. and DoD consumption. The interpretation of these figures is provided in the body of the report for aluminum and petroleum. The aluminum and petroleum diagrams have been repeated here to provide a complete set.

Table A-4

1972 DOD INDIRECT CONSUMPTION OF ALUMINUM FROM SECTOR 101-- ELECTRONIC COMPONENTS AND ACCESSORIES

(Thousand Short Tons)

		US CONS	TOTAL US SALES	CONS. FACTOR	FINAL DEMAND	CONSUMPTION DIRECT	CONSUMPTION INDUSTRIAL INDIRECT	CONSUMPTION SECTOR TOTAL	CONSUMPTION FINAL DEMAND INDIRECT	CONSUMPTION SECTOR TOTAL
101	ELECTRON COMPON . ACCESS	48	8502.39	.00562	259.978	1.462	6.493	7.955	1.650	3.111
15	NEW CONSTRUCTION							.009		0.000
17	MAIN. . REPAIR CONST. ALL OTHE							.009		.006
18	COMPLETE GUIDED MISSLES							.616		.000
19	TANK . TANK COMPONENTS							.022		.000
20	AMMUN. INC FOR SMALL ARMS							.230		.003
21	OTHER ORDNANCE . ACCESSORIES							.100		.000
31	HOUSEHOLD FURNITURE							.000		.010
35	PAPERBOARD CONTAINERS . BOXES							.000		.014
47-48	PETROL REFIN . RELATED INDUS							.008		0.000
55	BLAST FURN . BASIC STEEL PROD							.000		.024
58	PRIMARY IRON . STEEL PROD NEC							0.000		.008
64	COPPER ROLLING . DRAWING							0.000		.068
67	NONFERR WIRE DRAW . INSULATING							.001		.457
69	BRASS BRONZE . COPPER CASTINGS							.000		.044
70	NONFERR CASTINGS NEC							0.000		.014
72	METAL CONTAINERS							.000		.059
74	FAB STRUC SHEET . OTH MET PROD							.000		.050
75	SCREW MACHINE PRODUCTS							.000		.018
76	METAL STAMP INC AUTOMOBILES							.000		.162
77	OTHER FABRICATED METAL PROD							.000		.161
82	METALWORK MACHIN . EQUIP							.001		.013
87	MACHINE SHOP PRODUCTS							.000		.013
88	COMPUTING . RELATED MACHINES							.251		.003
92	ELEC MEAS INSTR							.108		.014
93	TRANSF SWITCHGR . BOARD APPAR							.003		.007
94	MOTORS CONTROL . ELEC PROD NEC							.023		.049
96	ELEC LIGHTING . WIRING EQUIP							.001		.046
97	RADIO . TV RECEIVING SETS							.080		.002
99	TELEPHONE . TELEGRAPH APPARAT							.054		.025
100	RADIO . TV COMMUNICATION EQUIP							3.851		.025
101	ELECTRON COMPON . ACCESS							1.764		1.764
103	BATT XRAY . OTH ELEC EQUIP							.009		.001
105	MOTOR VEHIC . PARTS							.022		.009
106	AIRCRAFT . COMPLETE							.381		.001
107	AIRCFT ENGN . PRT INC FOR MISS							.039		.001
108	AIRCRAFT EQUIP . PARTS NEC							.181		.004
109	SHIPBLDG . REPAIRING							.013		.000
110	SCI INSTRUM MEAS . CONTROLS							.085		.005
117	PHOTO EQUIP . SUPPLIES							.012		.001
122	AIR TRANSPORTATION							.009		0.000
125	COMMUNICATIONS EX RADIO . TV							.006		0.000
130	WHOLESALE . RETAIL TRADE							.009		0.000
138	MISC BUSN SERVCS EX ADVERTSG							.020		0.000

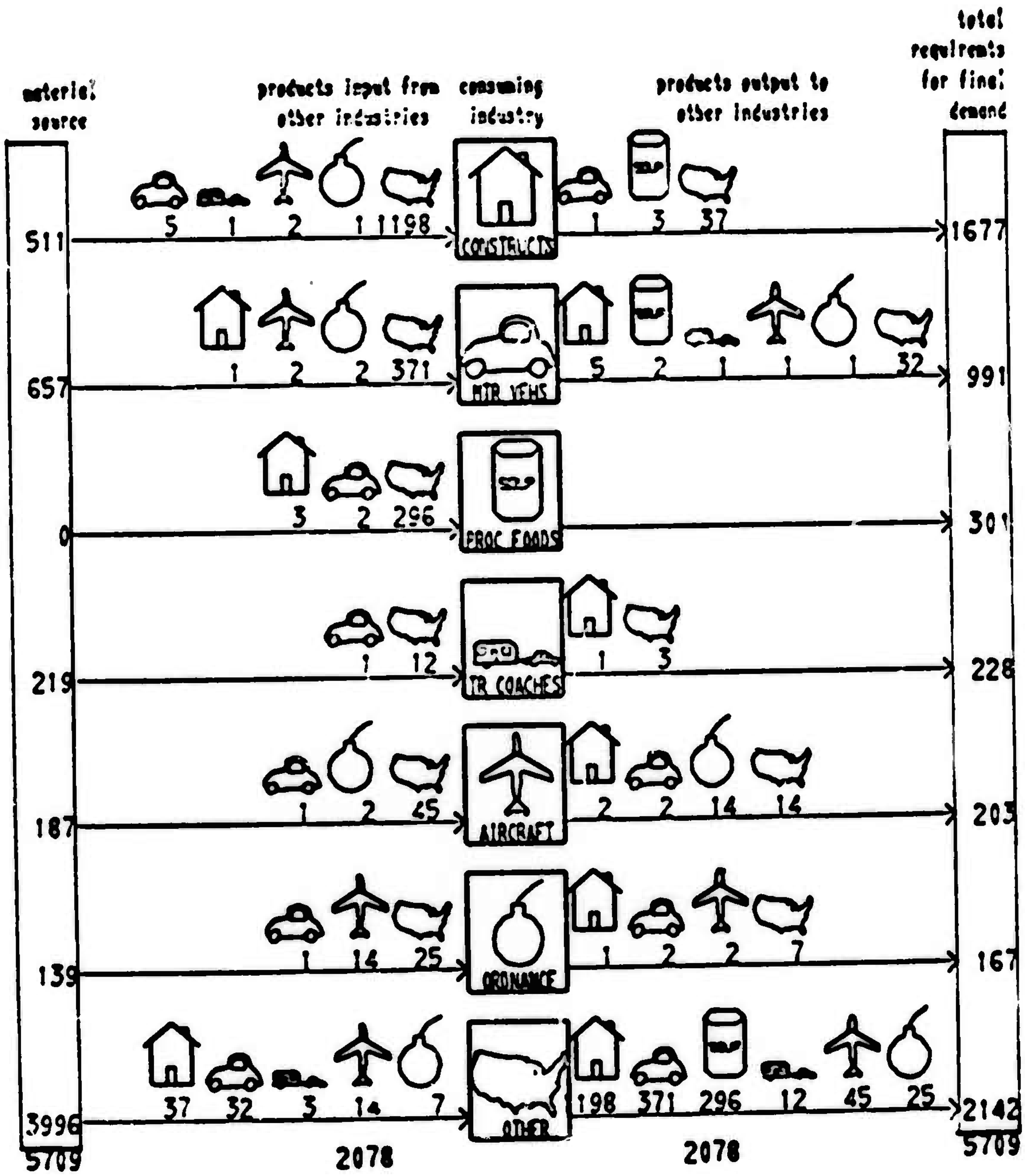


FIGURE A-1. 1972 ALUMINUM CONSUMPTION BY THE U.S.
THOUSANDS SHORT TONS

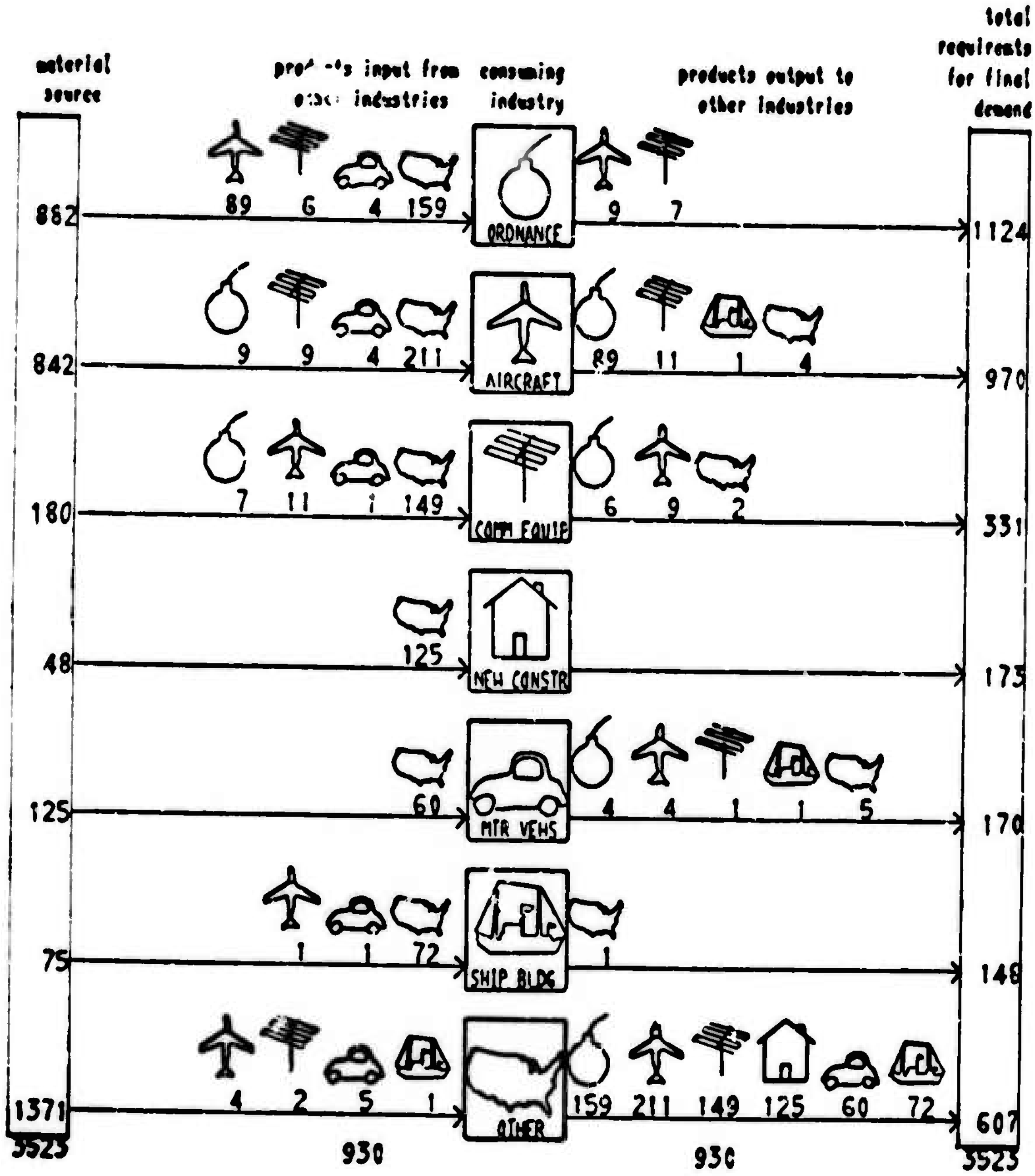


FIGURE A-2. 1972 ALUMINUM CONSUMPTION BY THE DOD
HUNDREDS SHORT TONS

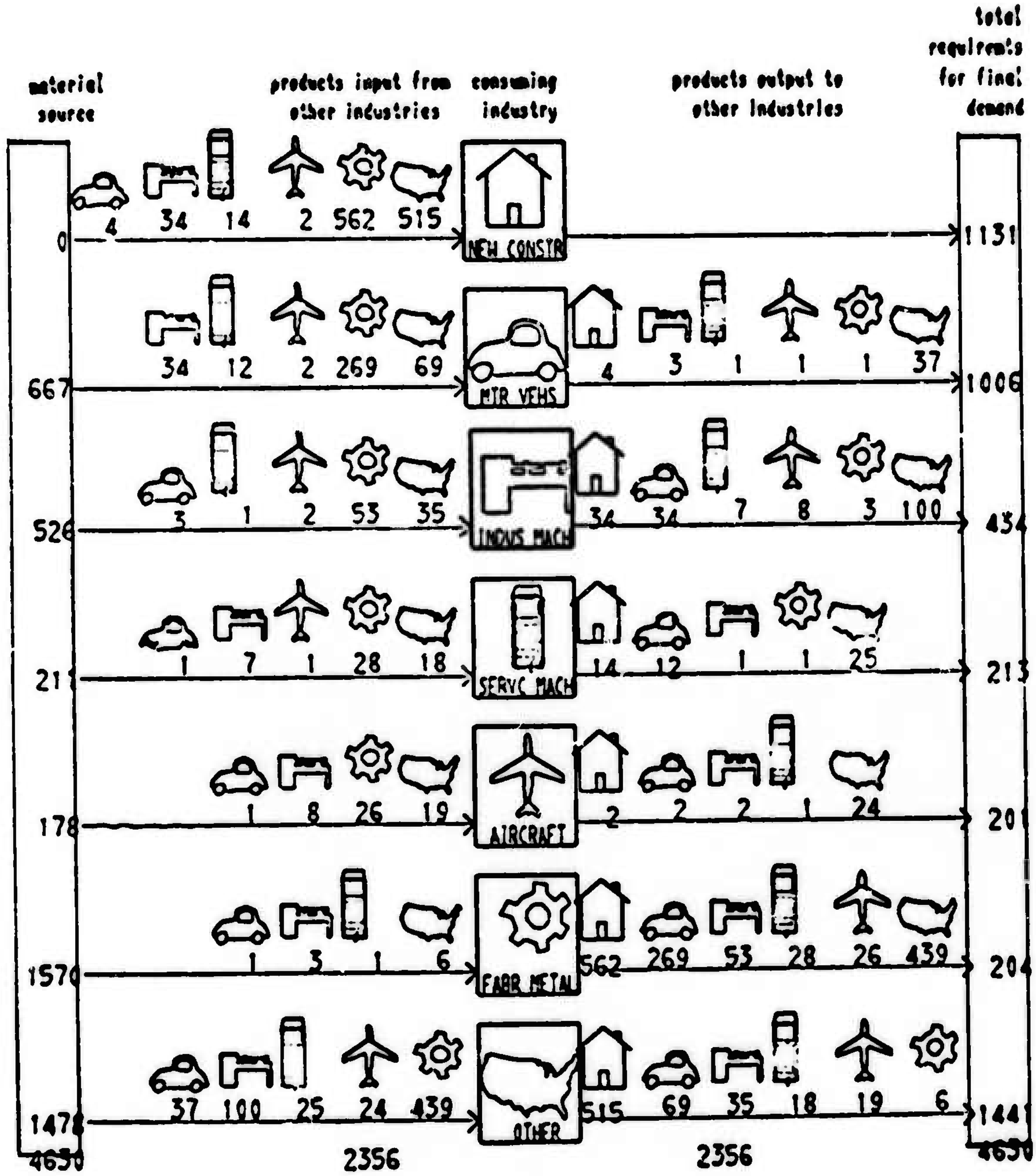


FIGURE A-3. 1972 CHROMIUM CONSUMPTION BY THE U.S.
HUNDREDS SHORT TONS

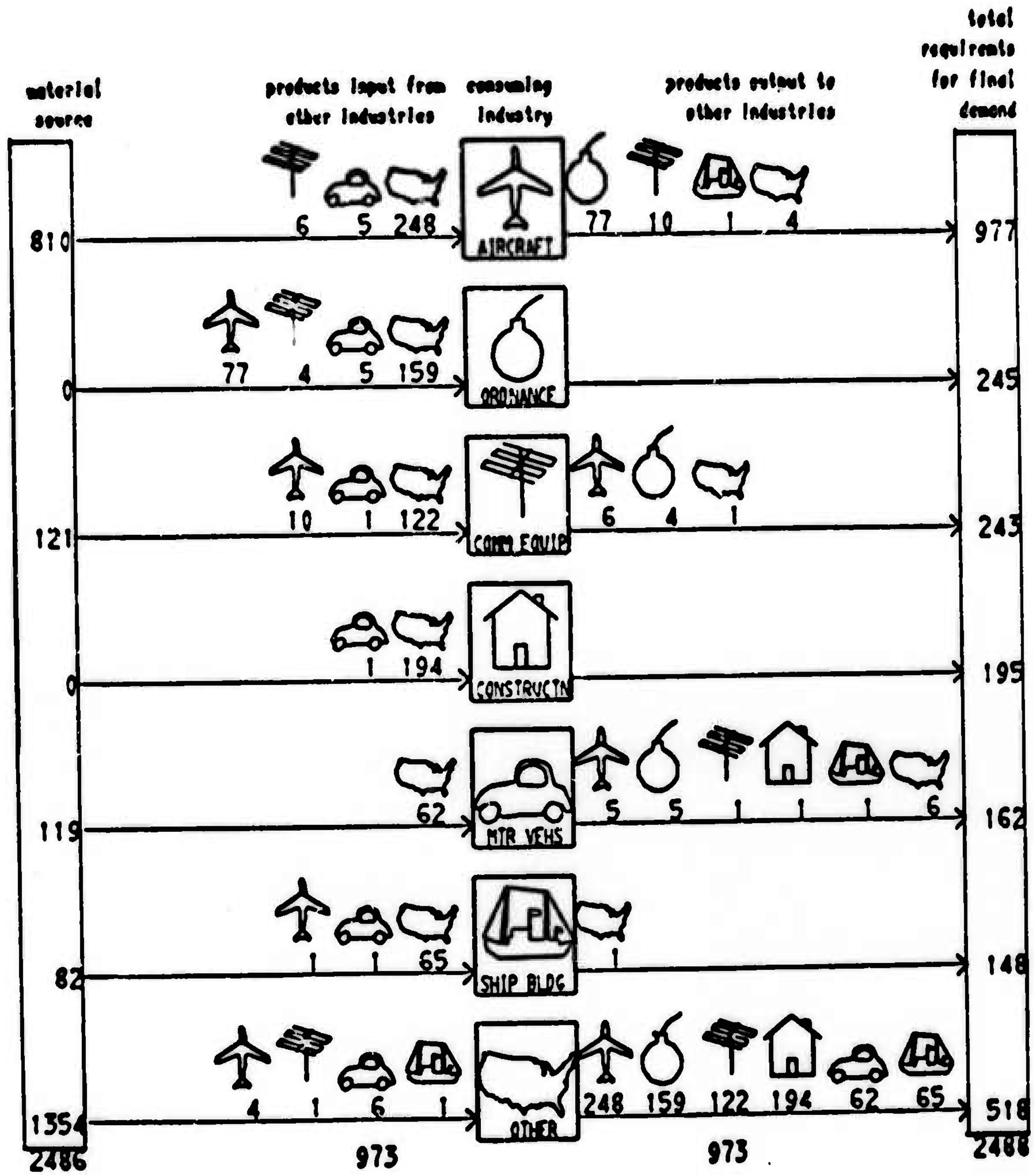


FIGURE A-4. 1972 CHROMIUM CONSUMPTION BY THE DOD
TENS OF SHORT TONS

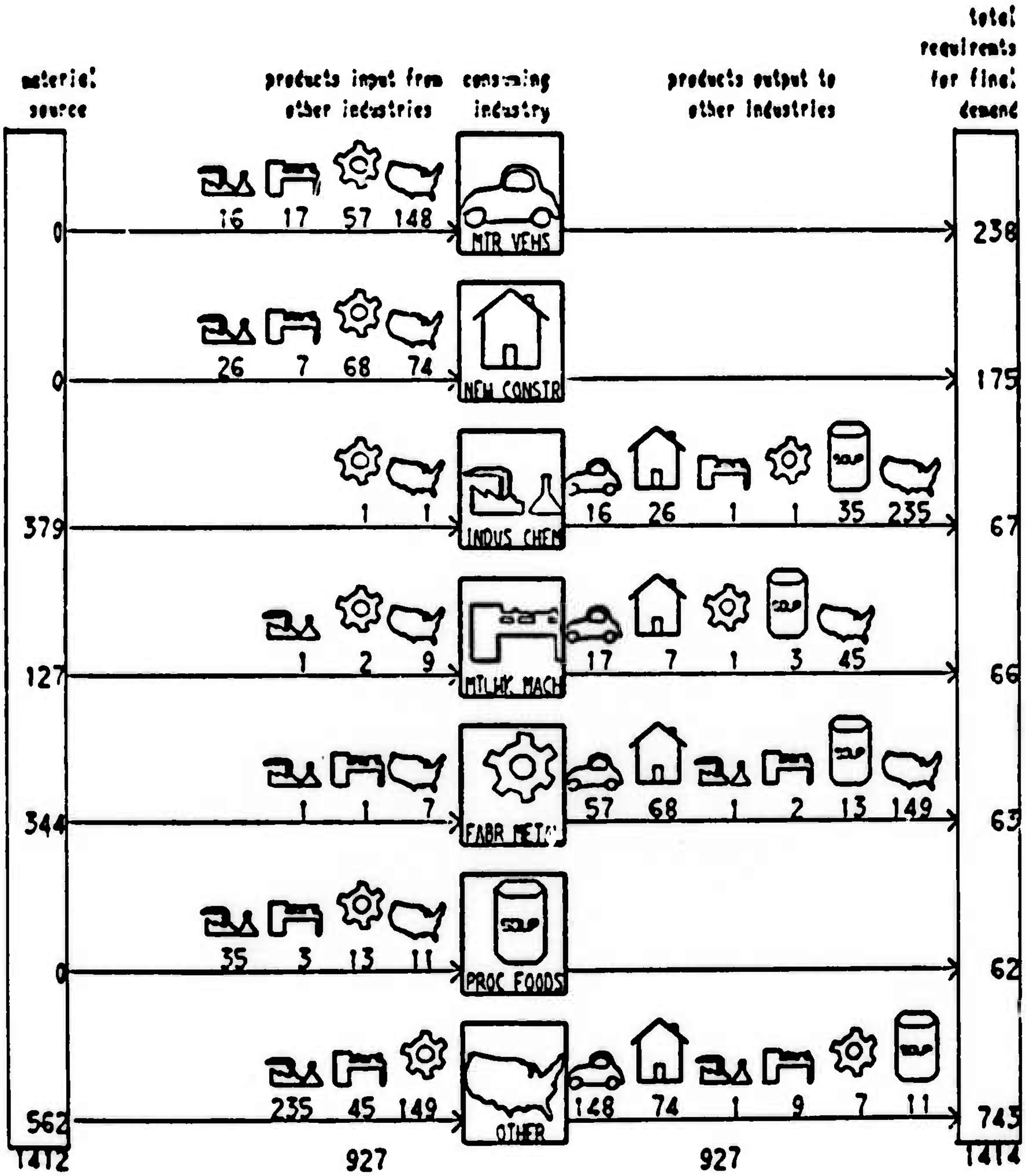


FIGURE A-5. 1972 COBALT CONSUMPTION BY THE U.S.
TEN THOUSAND POUNDS

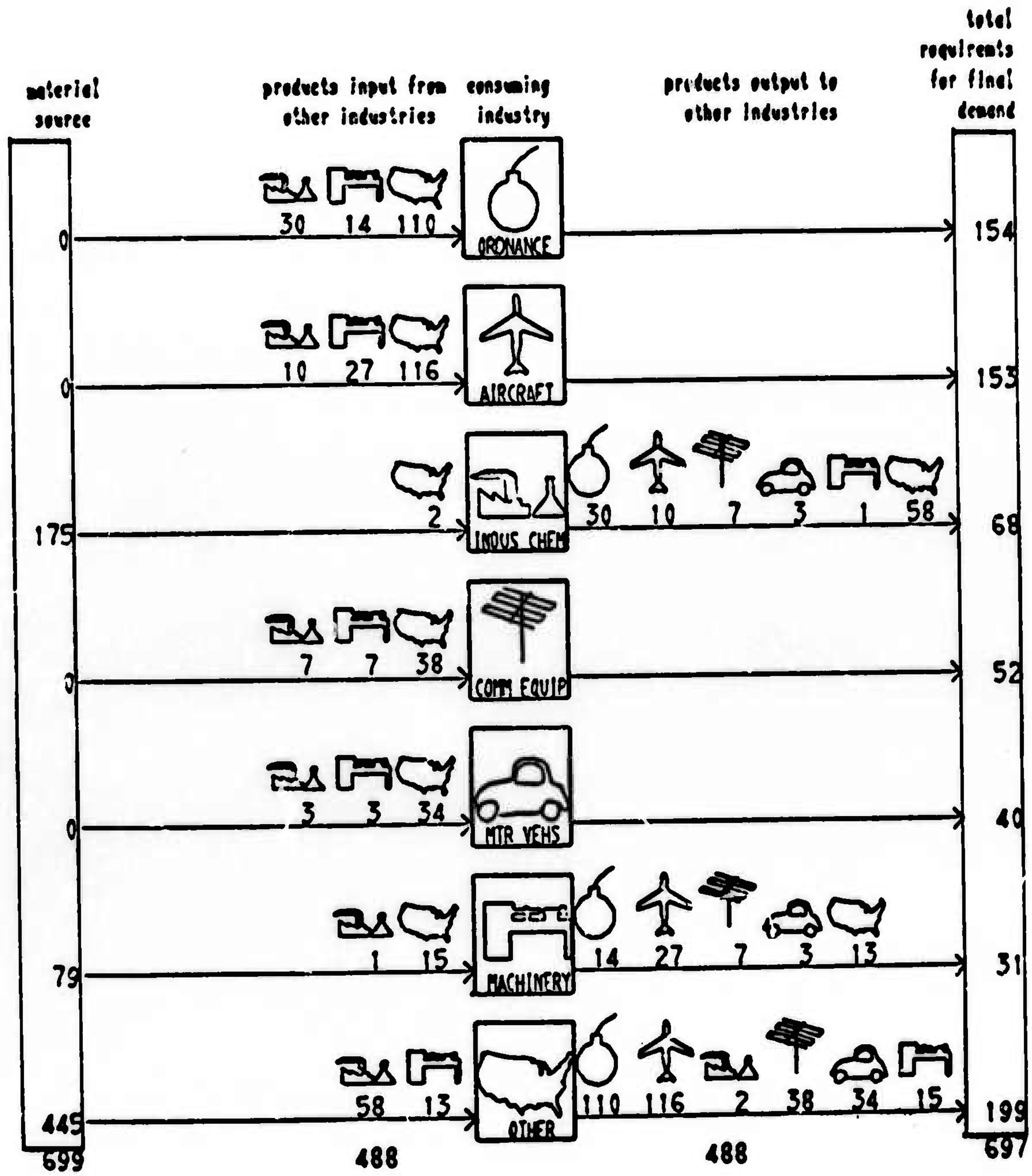


FIGURE A-6. 1972 COBALT CONSUMPTION BY THE DOD
THOUSANDS OF POUNDS

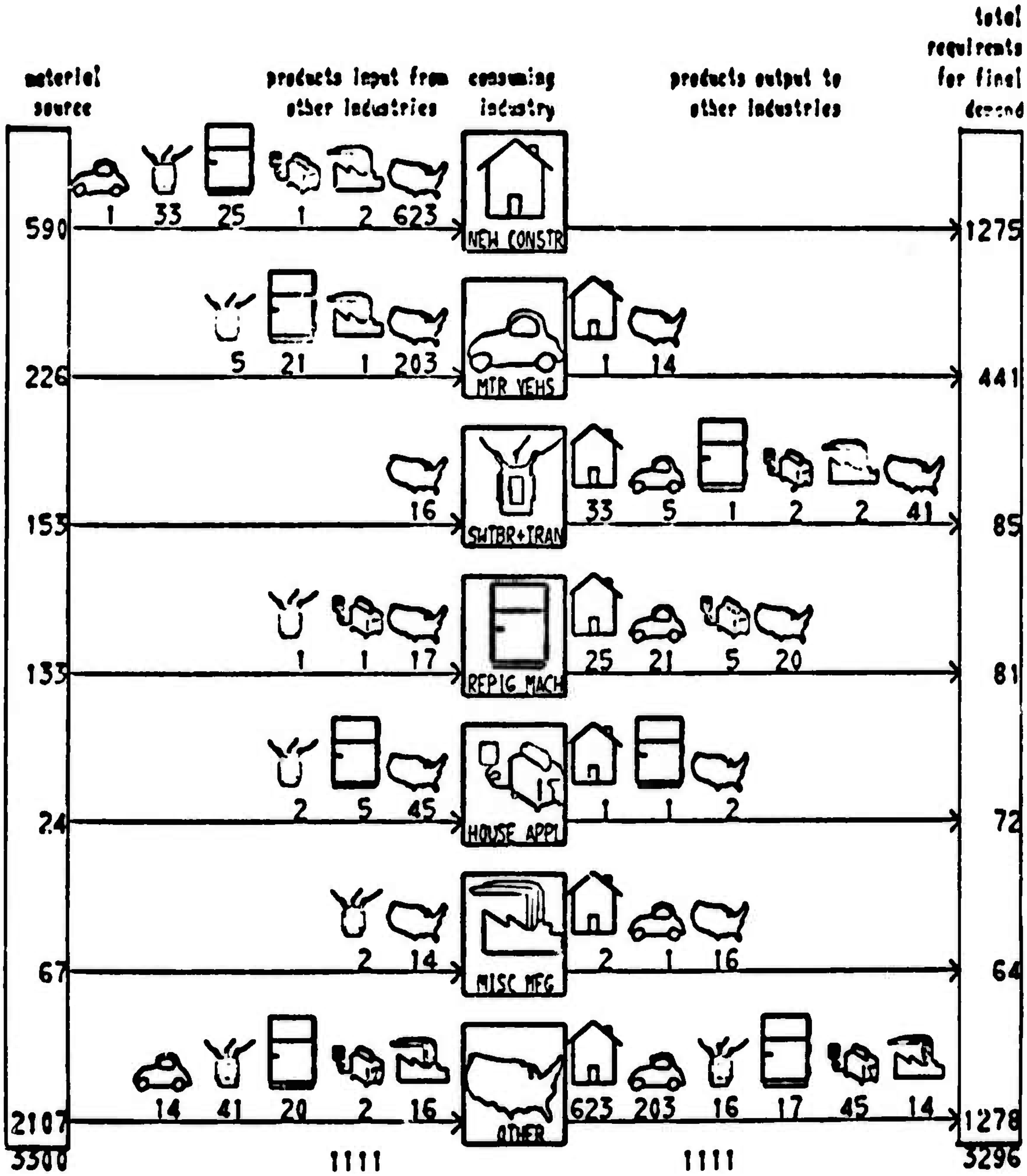


FIGURE A-7. 1972 COPPER CONSUMPTION BY THE U.S.
THOUSANDS SHORT TONS

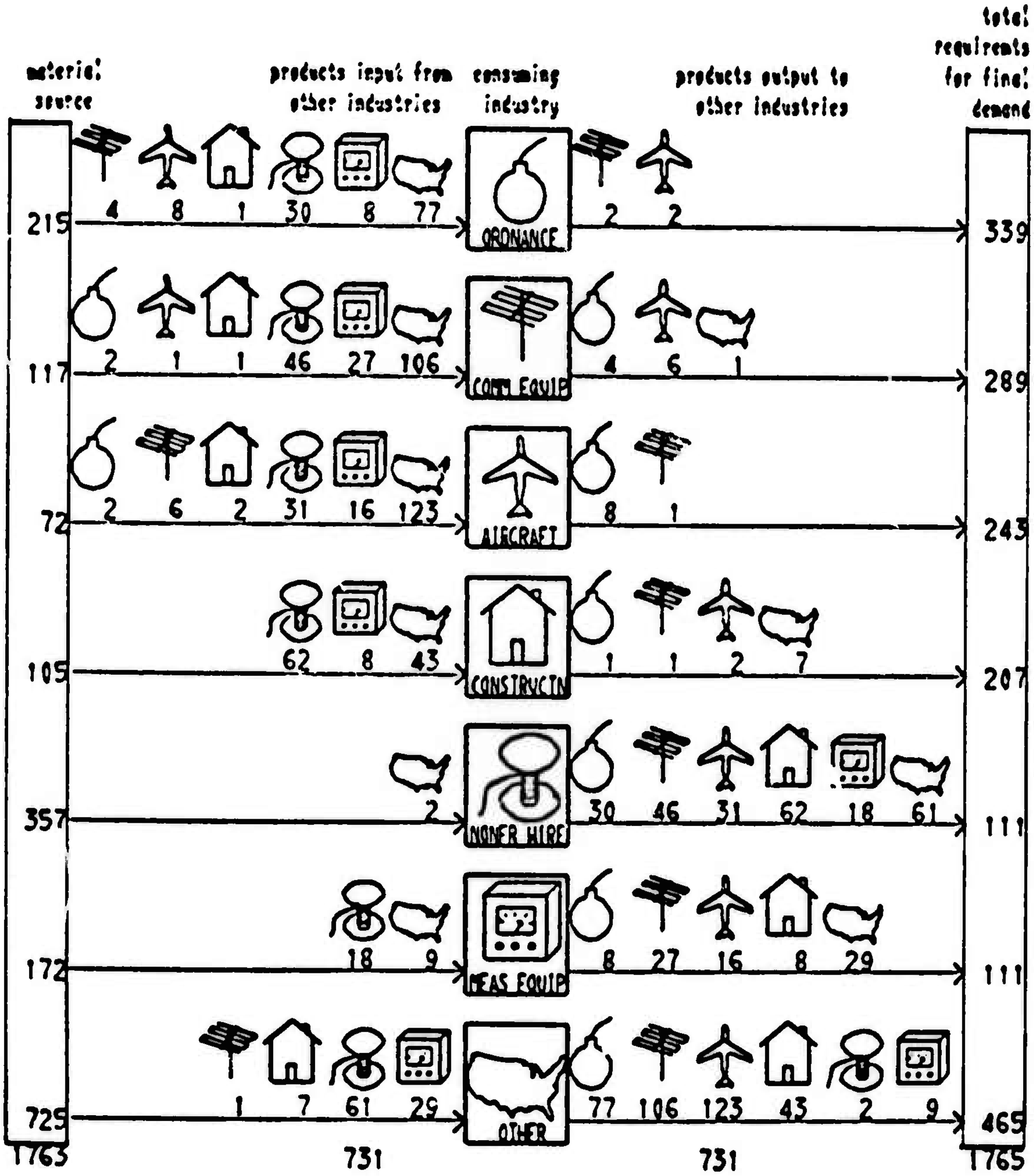


FIGURE A-8. 1972 COPPER CONSUMPTION BY THE DOD
HUNDREDS SHORT TONS

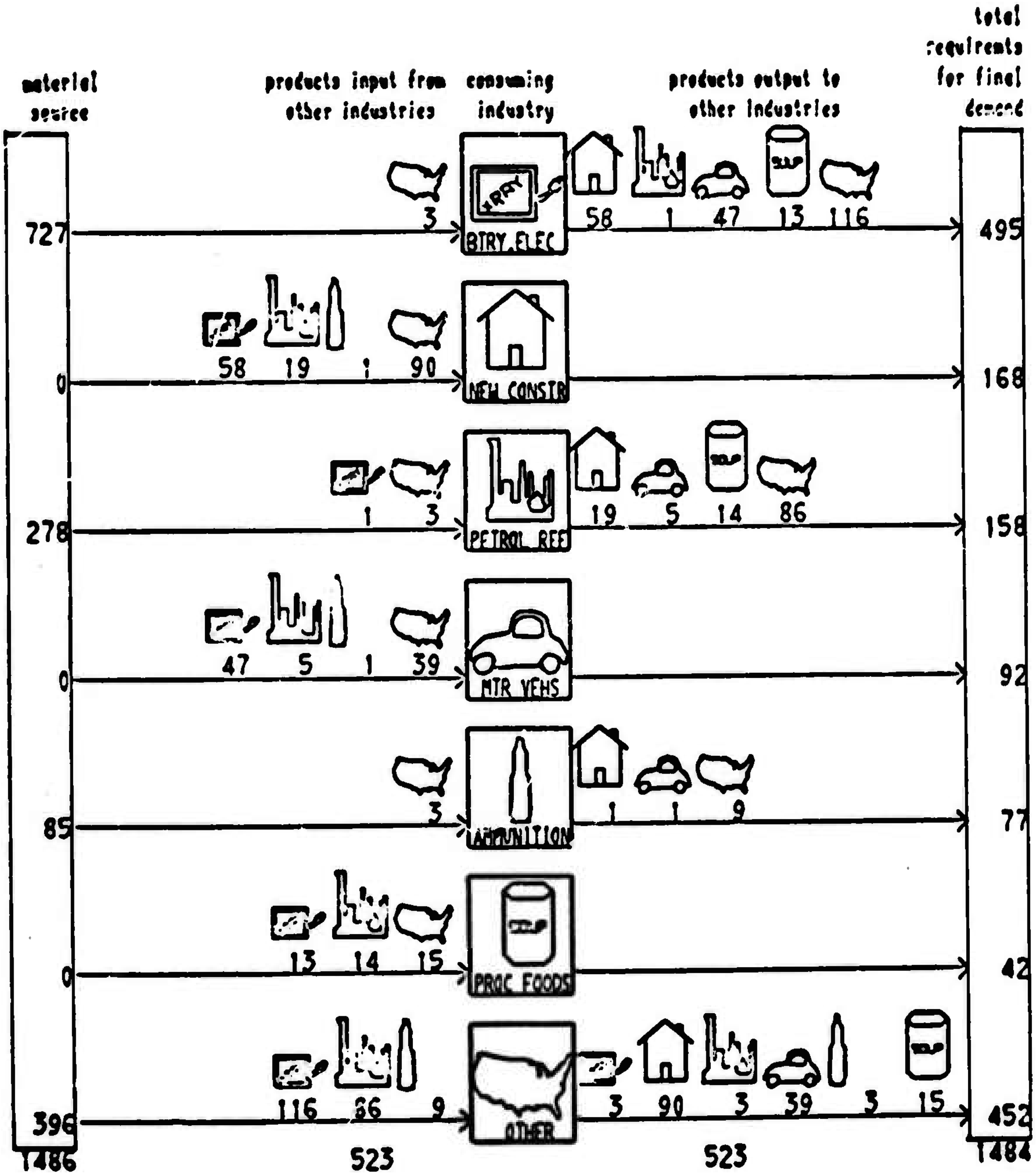


FIGURE A-9. 1972 LEAD CONSUMPTION BY THE U.S.
THOUSANDS SHORT TONS

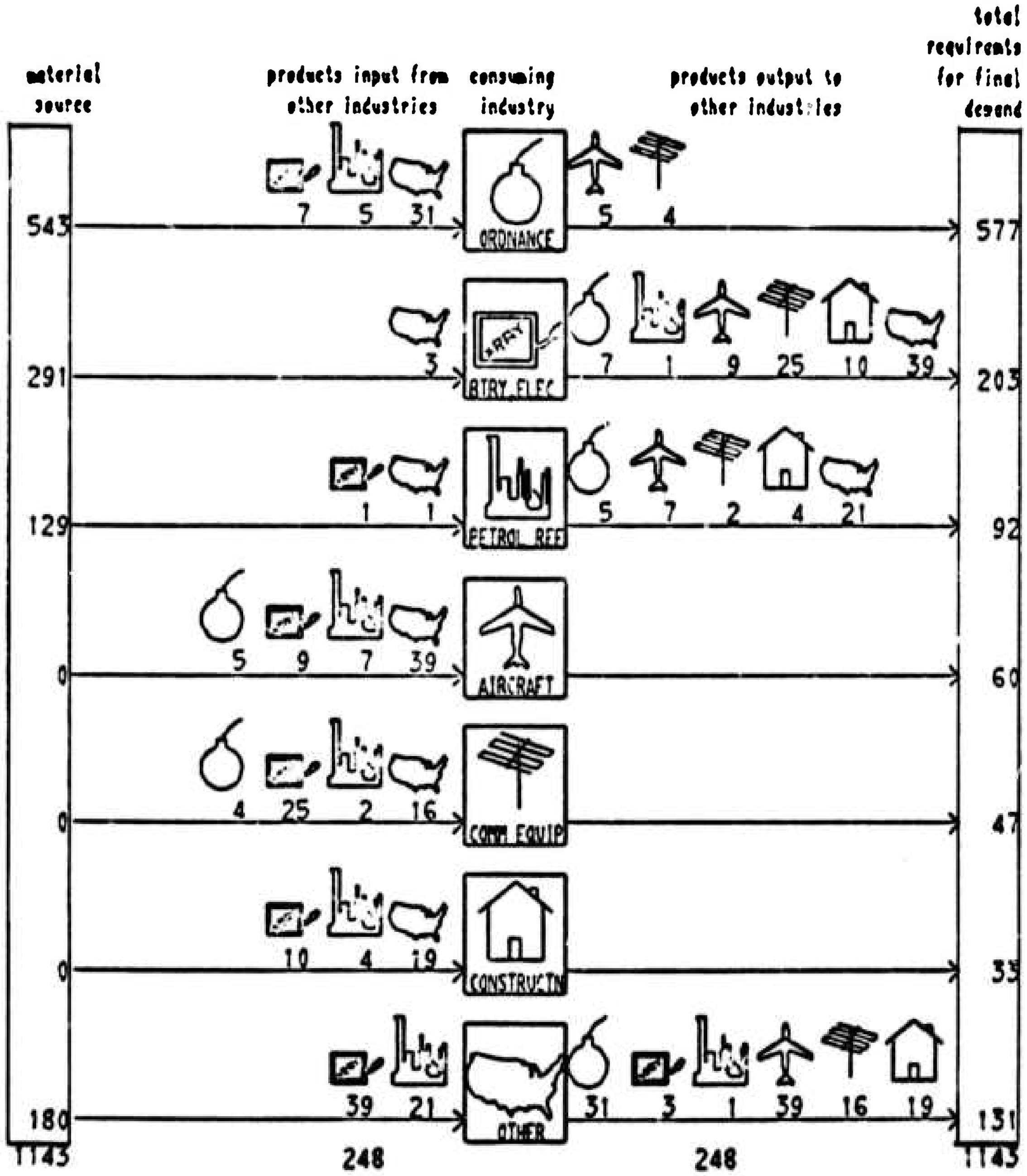


FIGURE A-10. 1972 LEAD CONSUMPTION BY THE DOD
HUNDREDS SHORT TONS

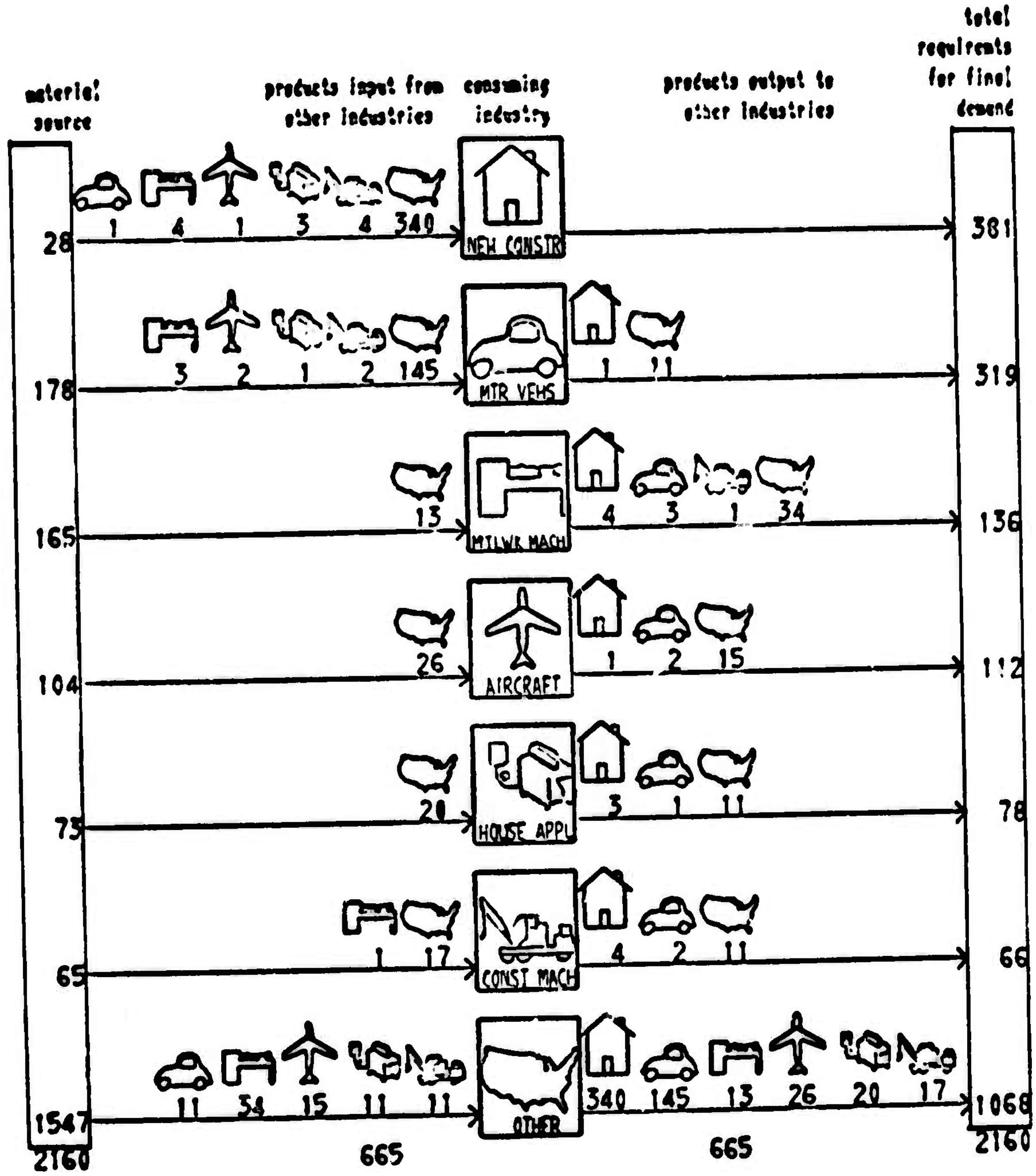


FIGURE A-11. 1972 NICKEL CONSUMPTION BY THE U.S.
HUNDREDS SHORT TONS

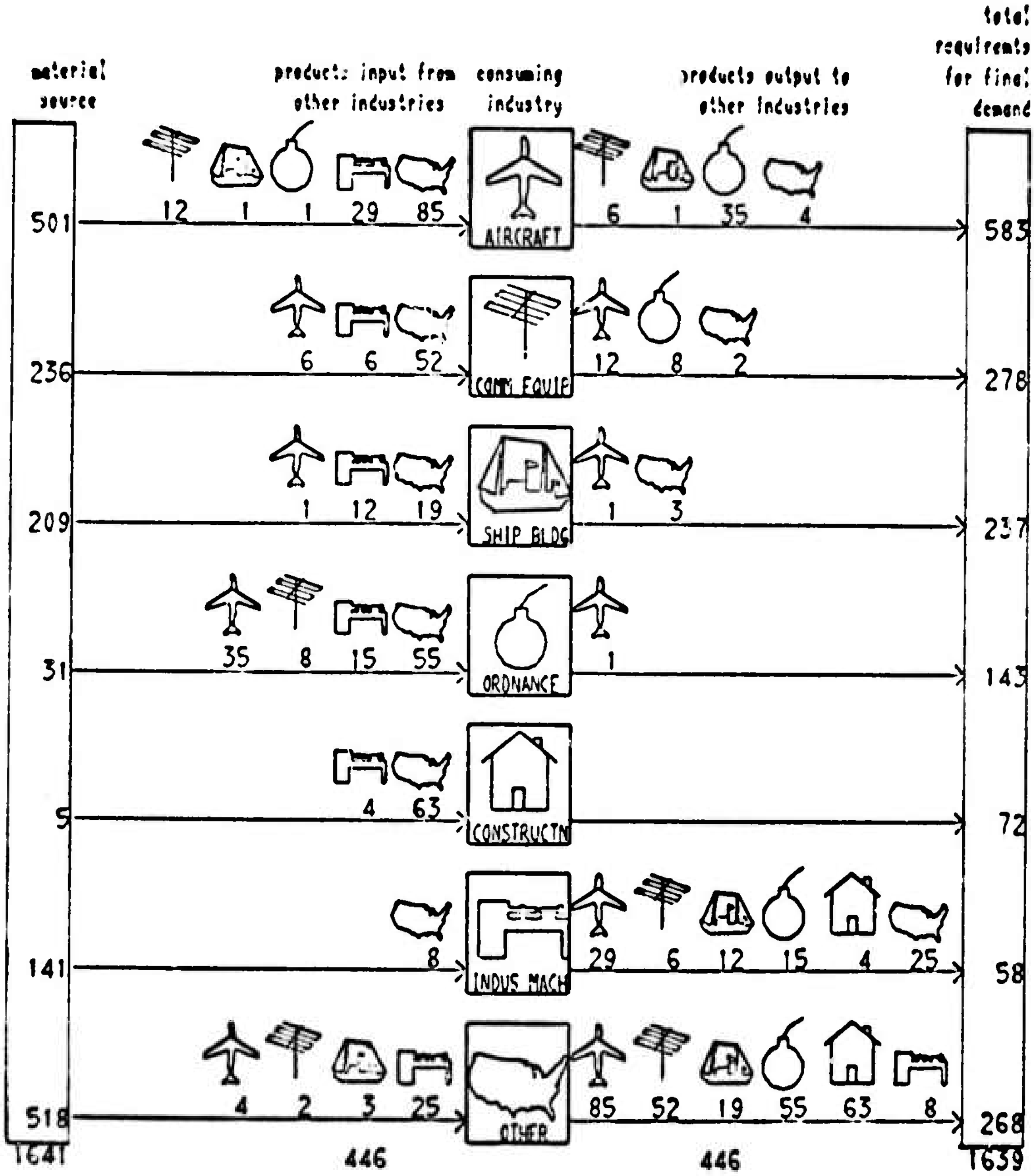


FIGURE A-12 1972 NICKEL CONSUMPTION BY THE DOD
TENS OF SHORT TONS

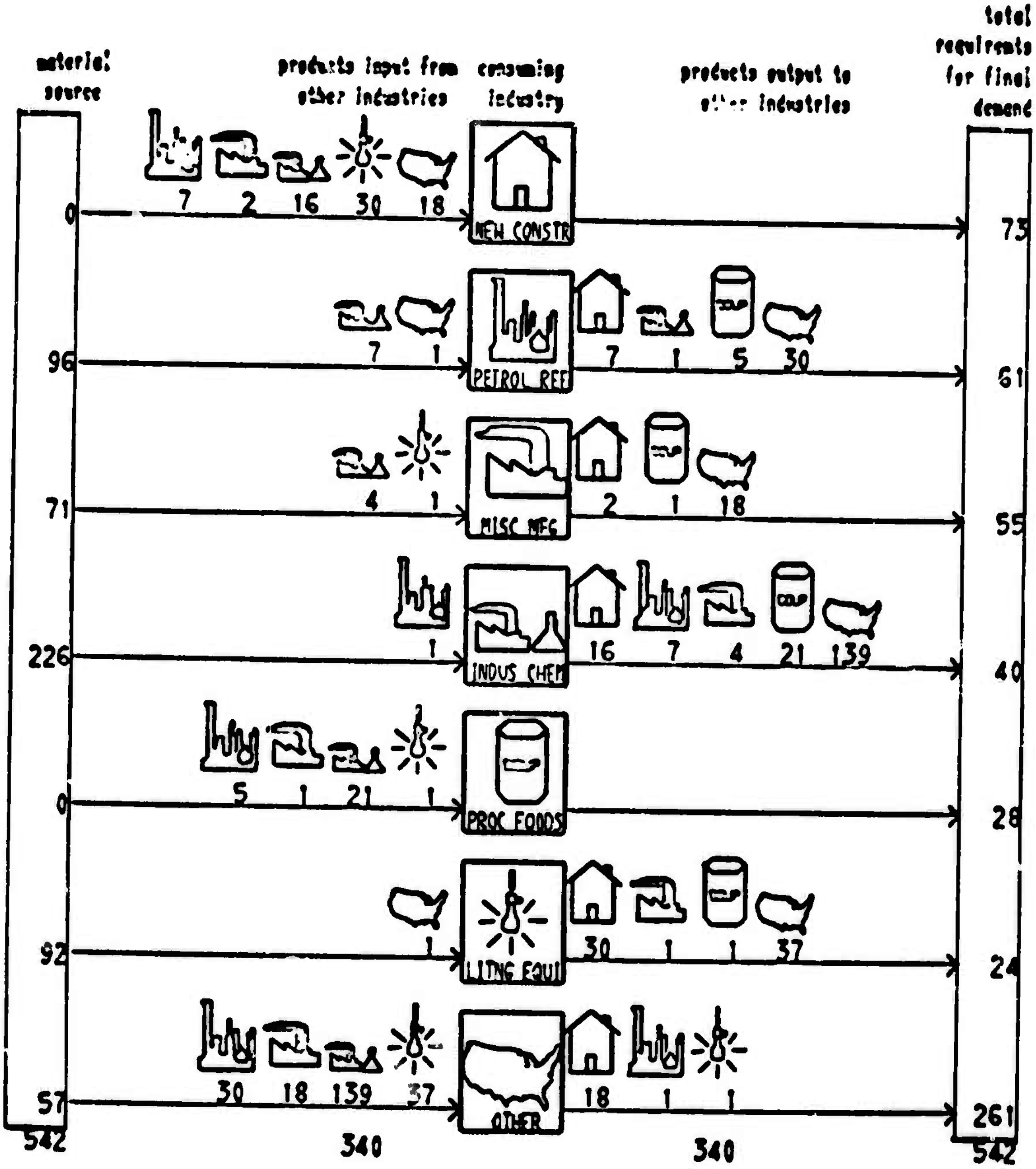


FIGURE A-13. 1972 PLATINUM CONSUMPTION BY THE U.S.
THOUSAND TROY OUNCES

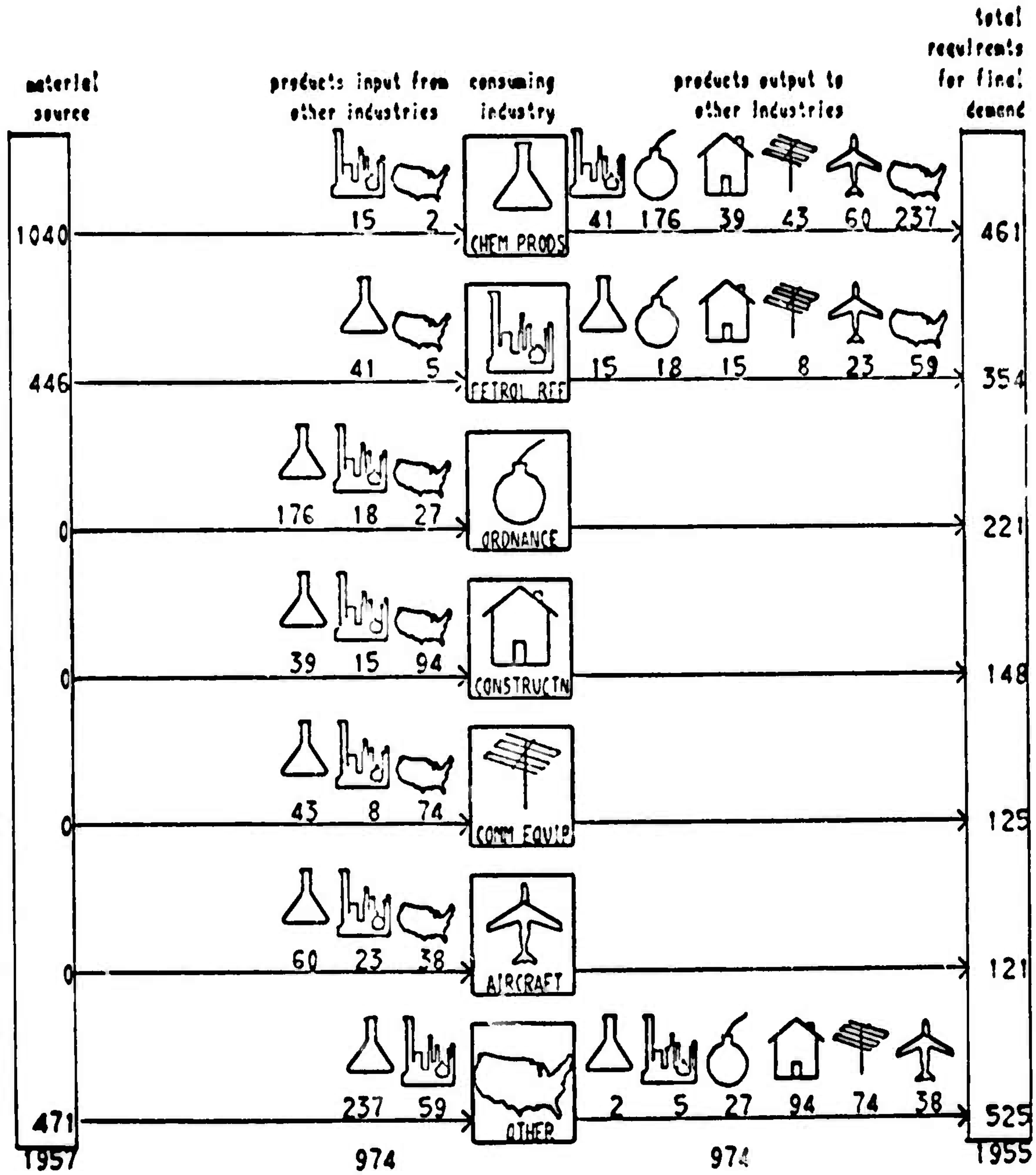


FIGURE A-14. 1972 PLATINUM CONSUMPTION BY THE DOD
TENS OF TROY OUNCES

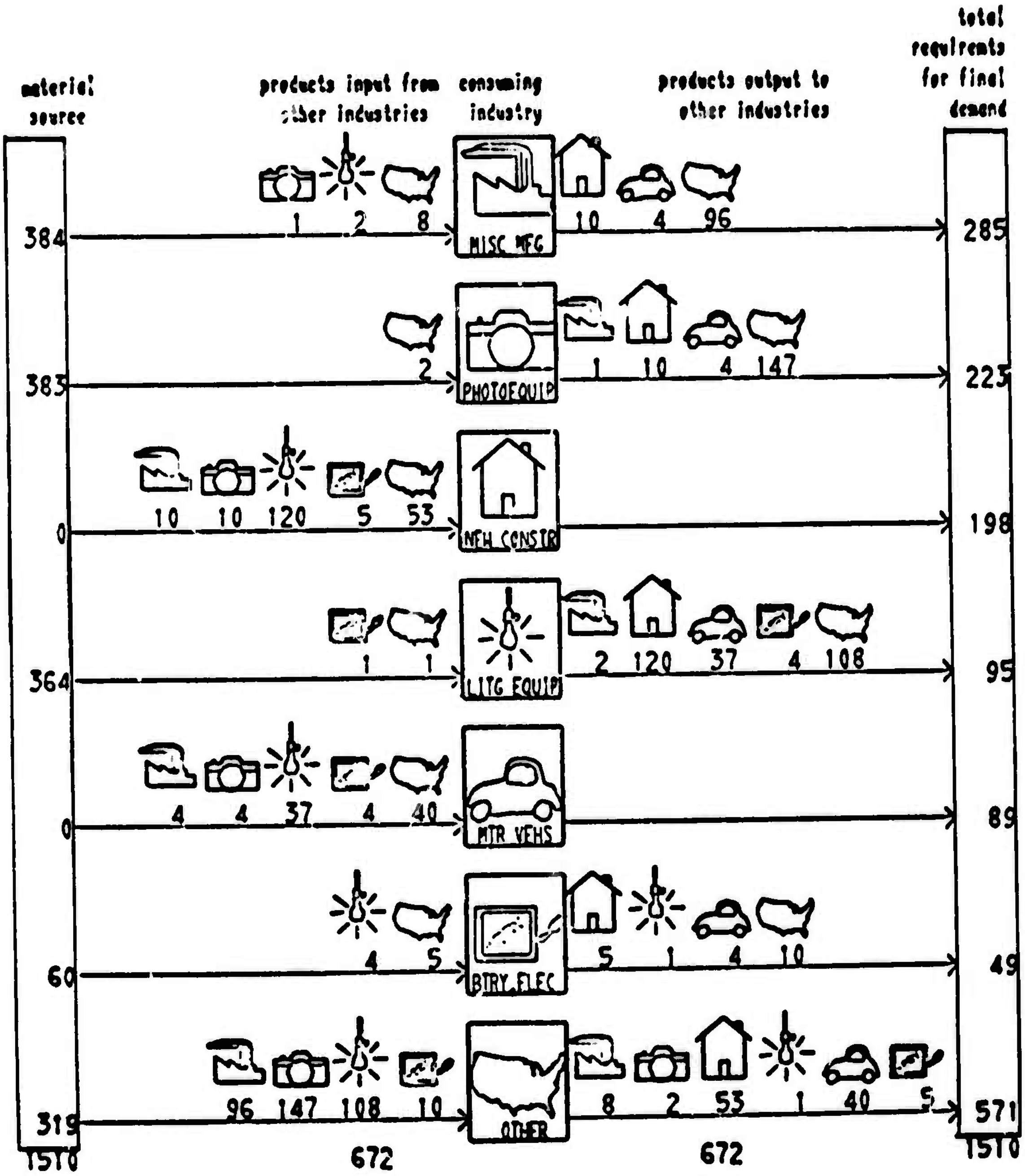


FIGURE A-15. 1972 SILVER CONSUMPTION BY THE U.S.
100,000 TROY OUNCES

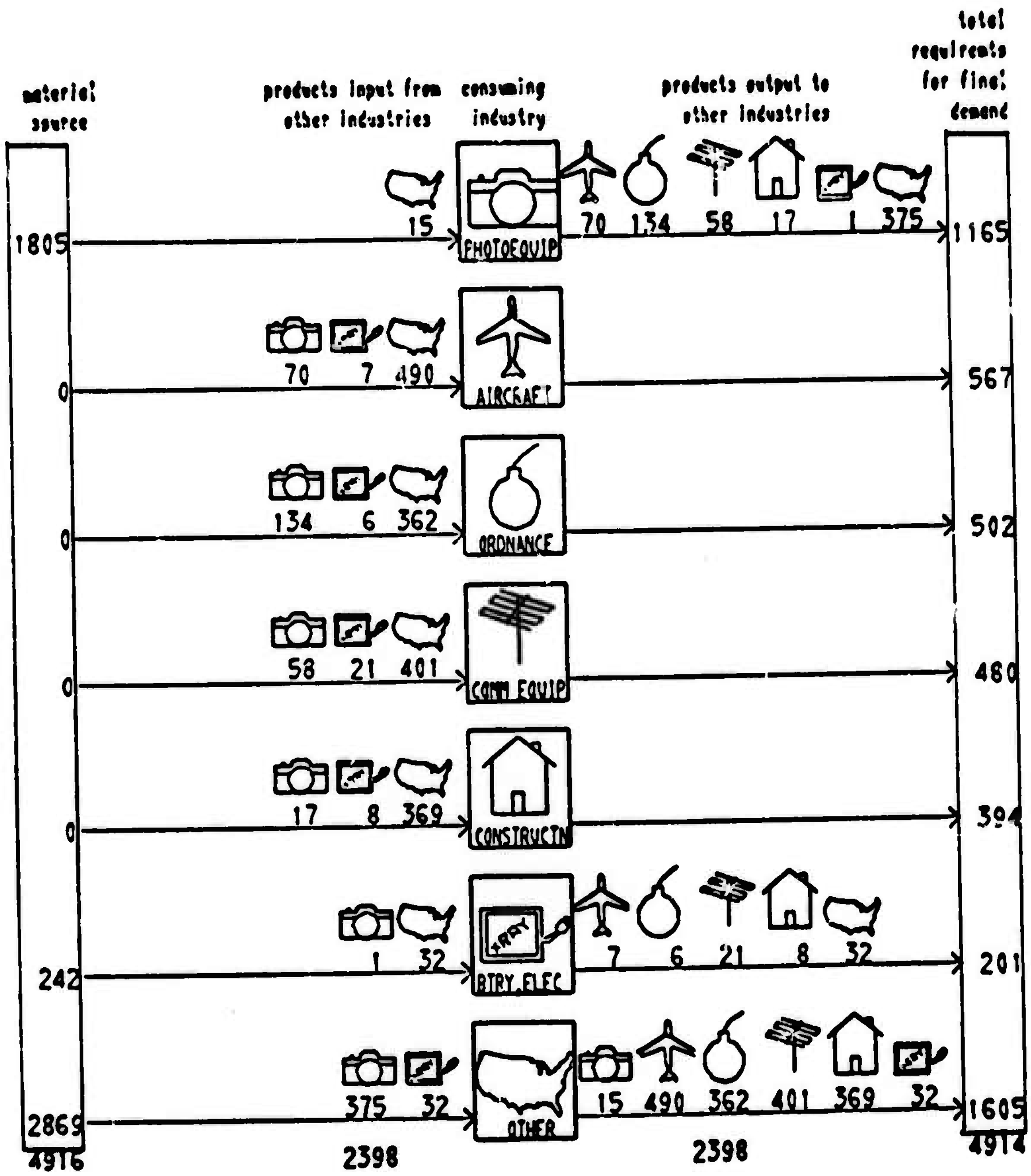


FIGURE A-16. 1972 SILVER CONSUMPTION BY THE DOD
THOUSAND TROY OUNCES

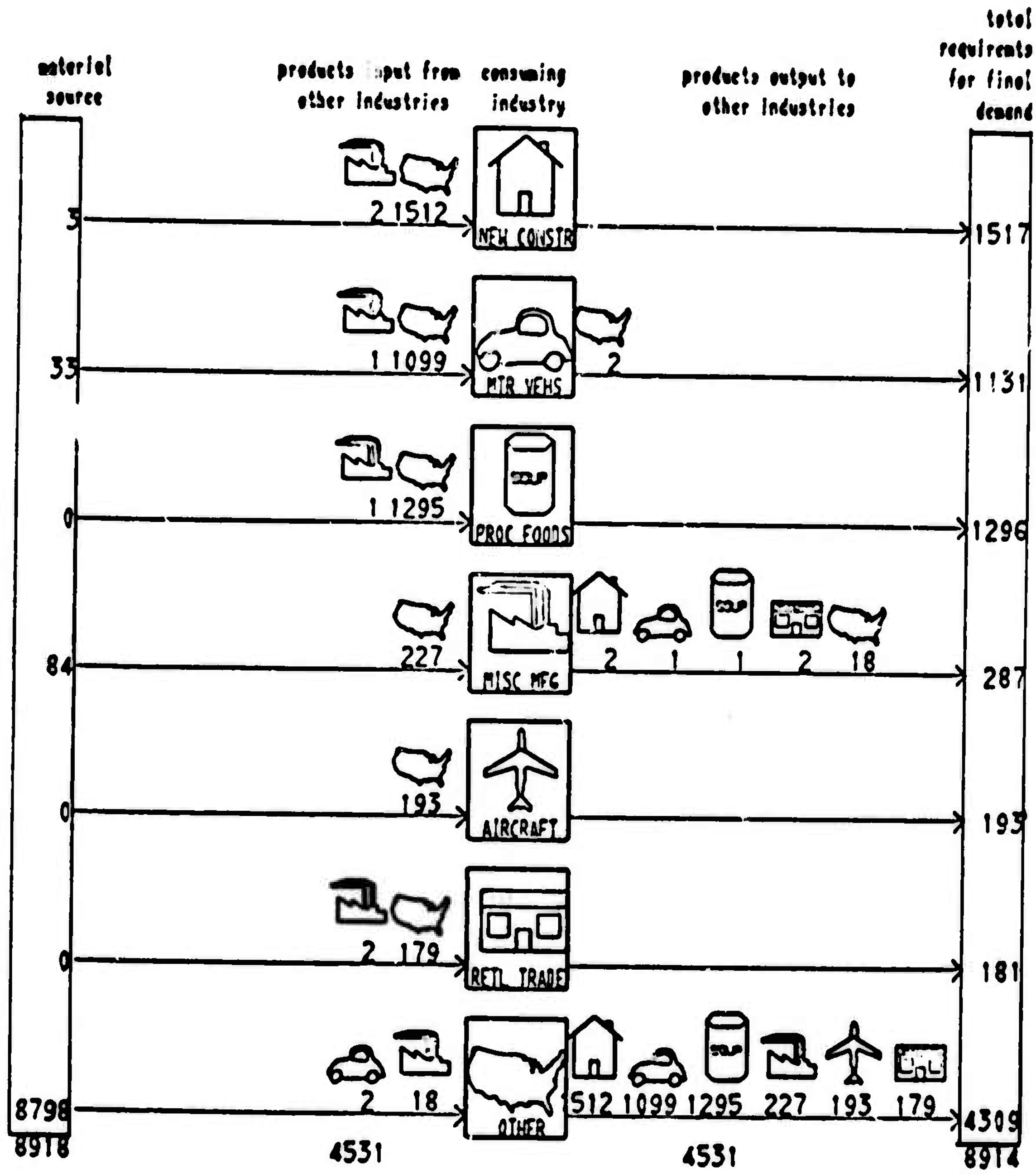


FIGURE A-17. 1972 TIN CONSUMPTION BY THE U.S.
TENS OF LONG TONS

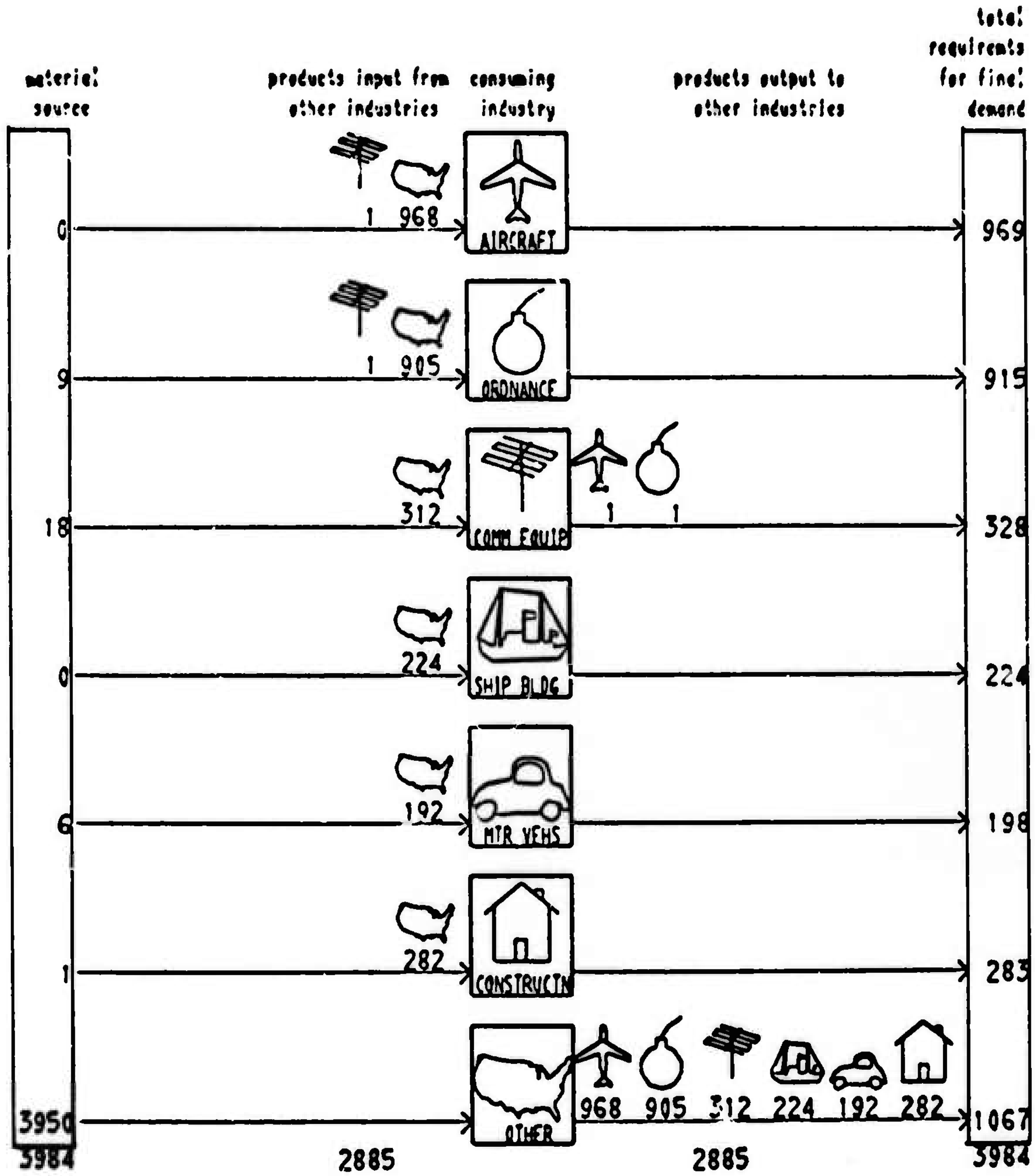


FIGURE A-18. 1972 TIN CONSUMPTION BY THE DOD
LONG TONS

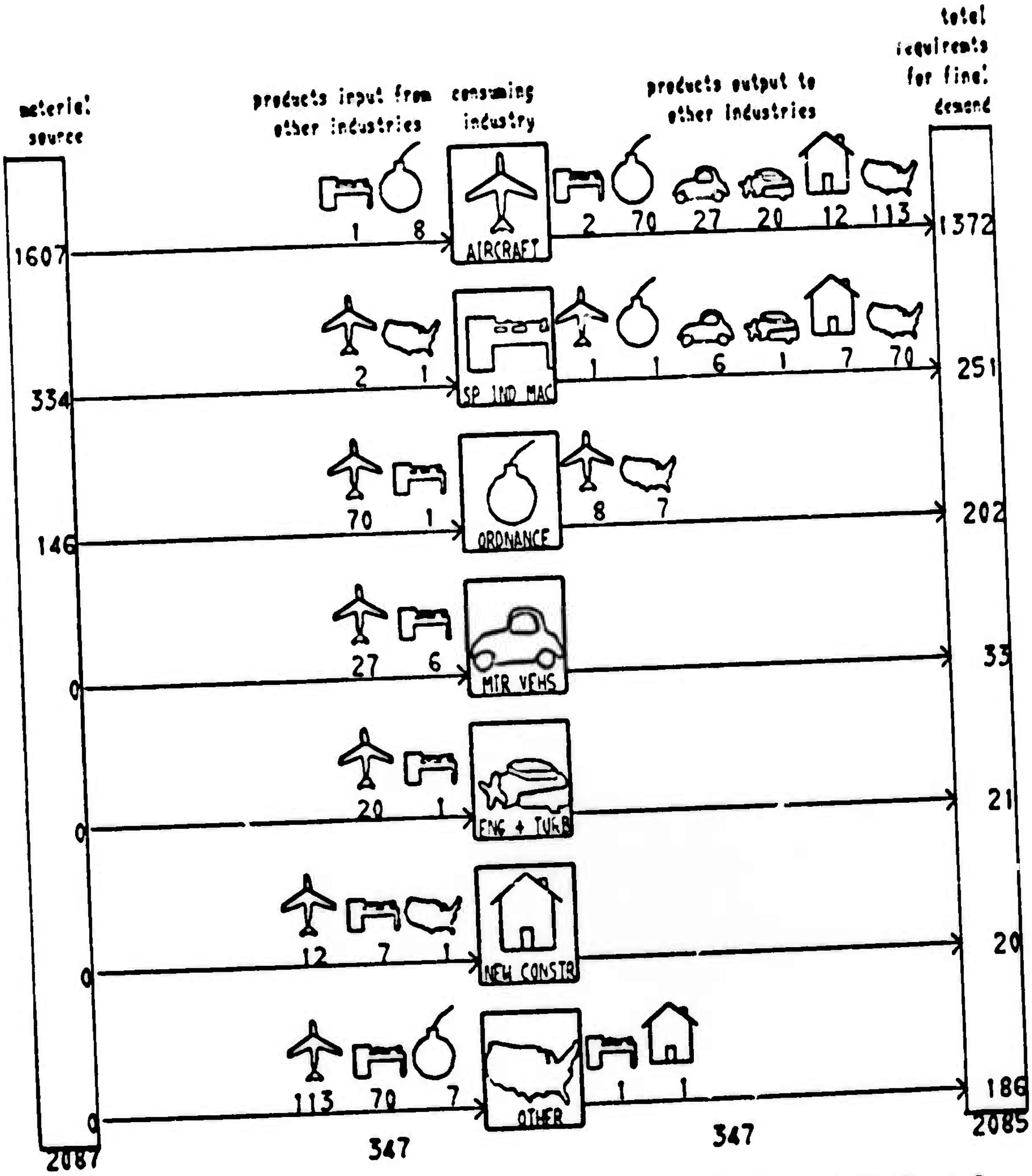


FIGURE A-19. 1972 M.TITANIUM CONSUMPTION BY THE U.S.
TENS OF SHORT TONS

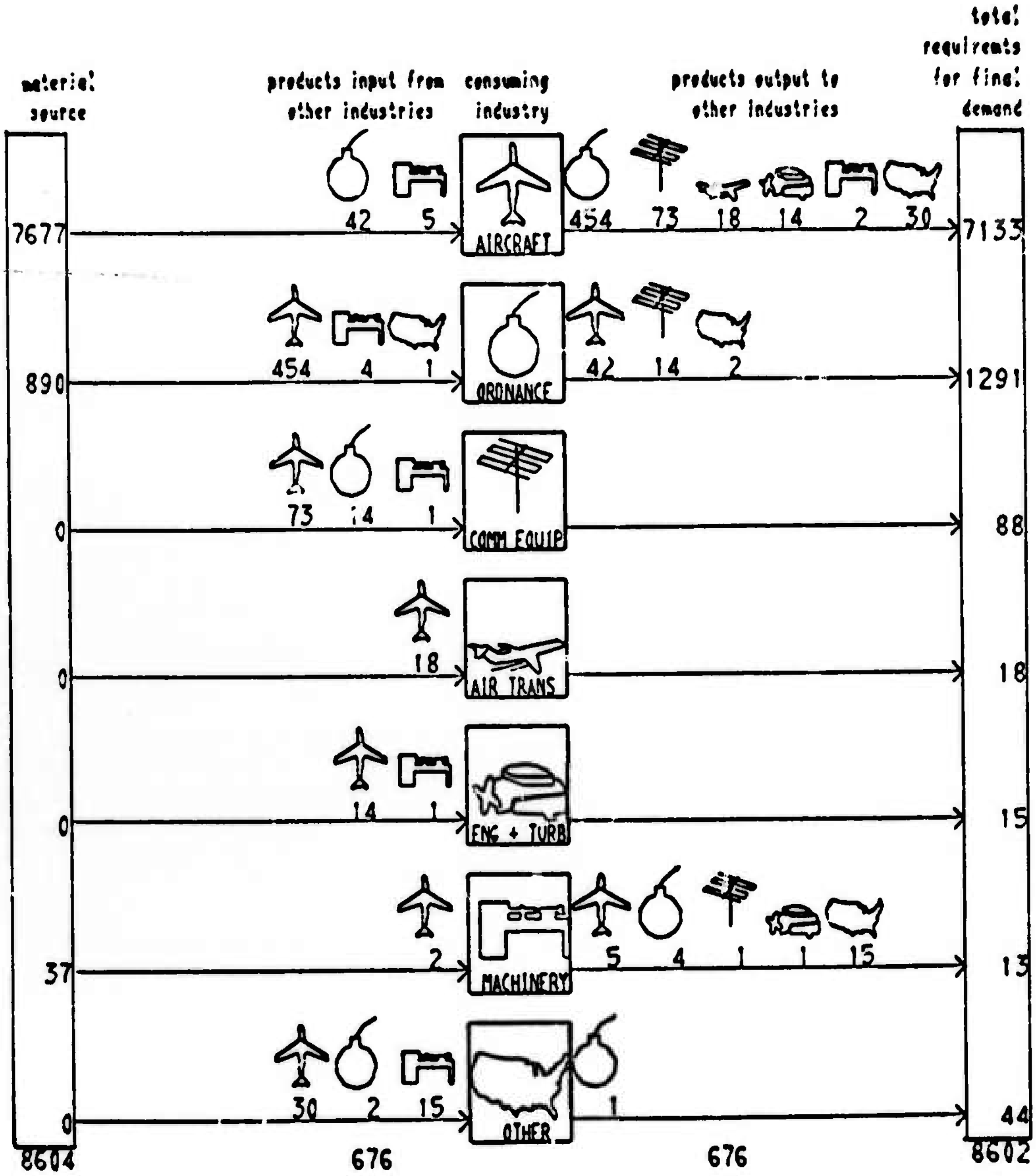


FIGURE A-20. 1972 M.TITANIUM CONSUMPTION BY THE DOD
SHORT TONS

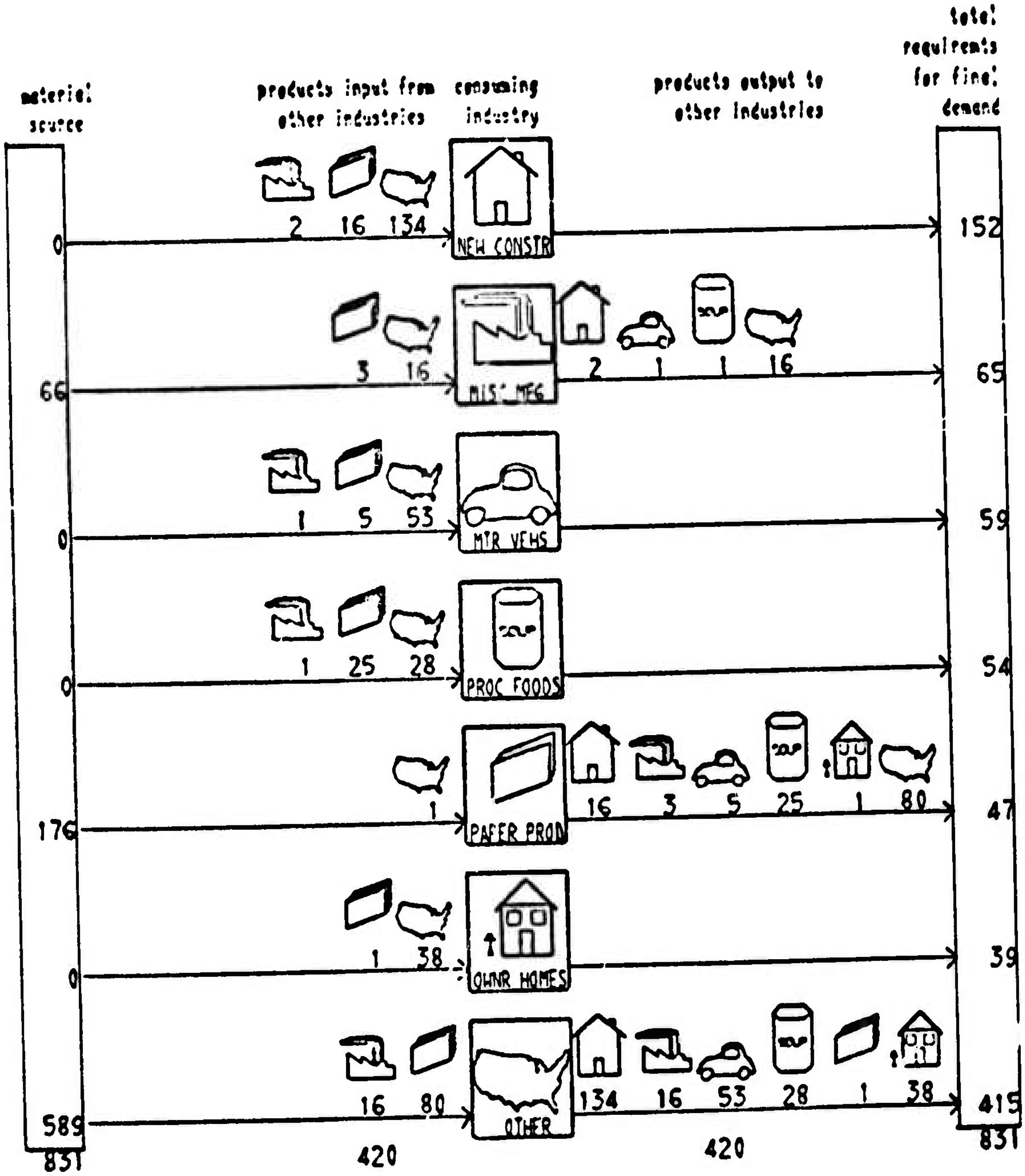


FIGURE A-21. 1972 NMTITANIUM CONSUMPTION BY THE U.S.
THOUSANDS SHORT TONS

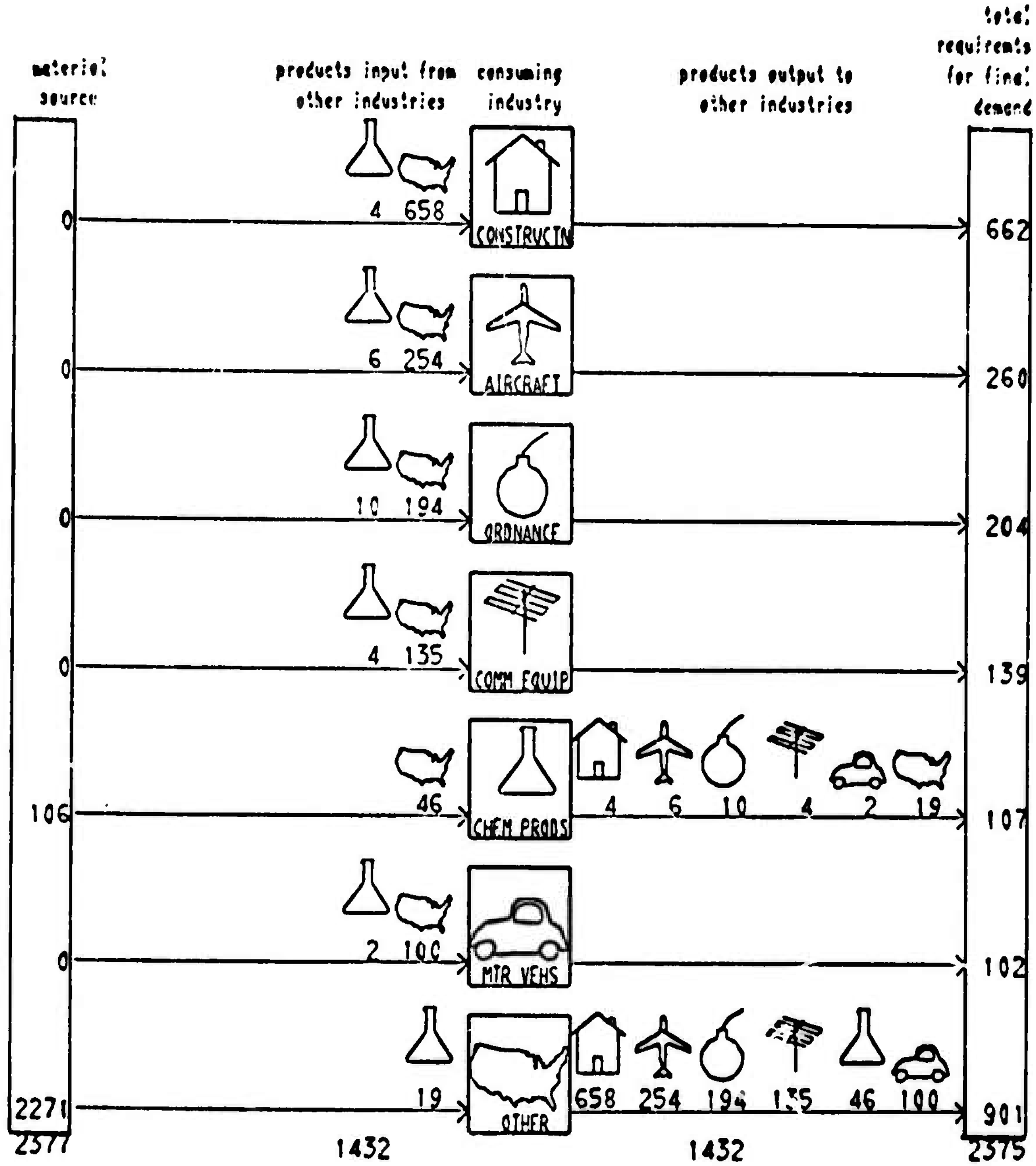


FIGURE A-22. 1972 NMTITANIUM CONSUMPTION BY THE DOD
TENS OF SHORT TONS

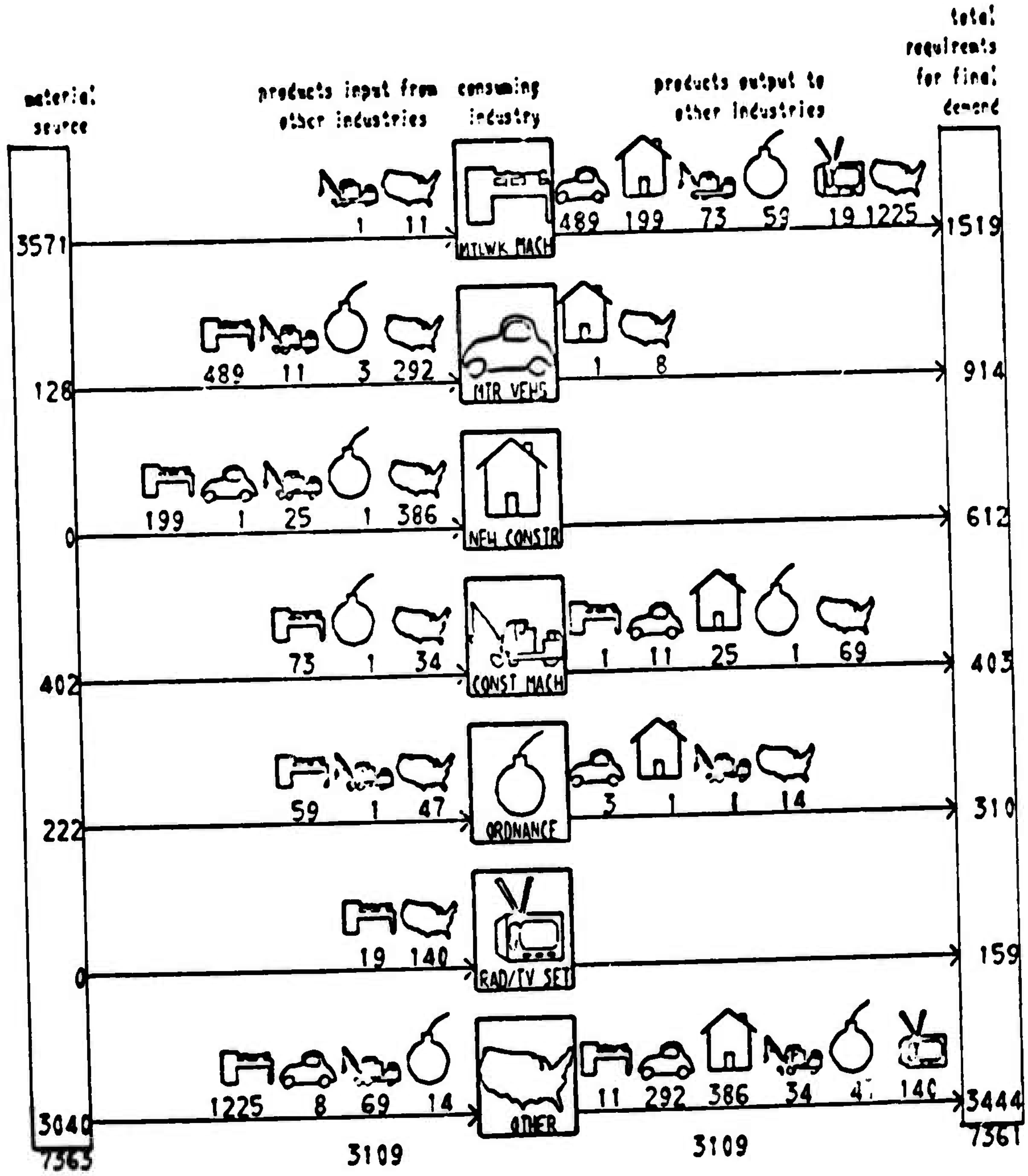


FIGURE A-23. 1972 TUNGSTEN CONSUMPTION BY THE U.S.
SHORT TONS

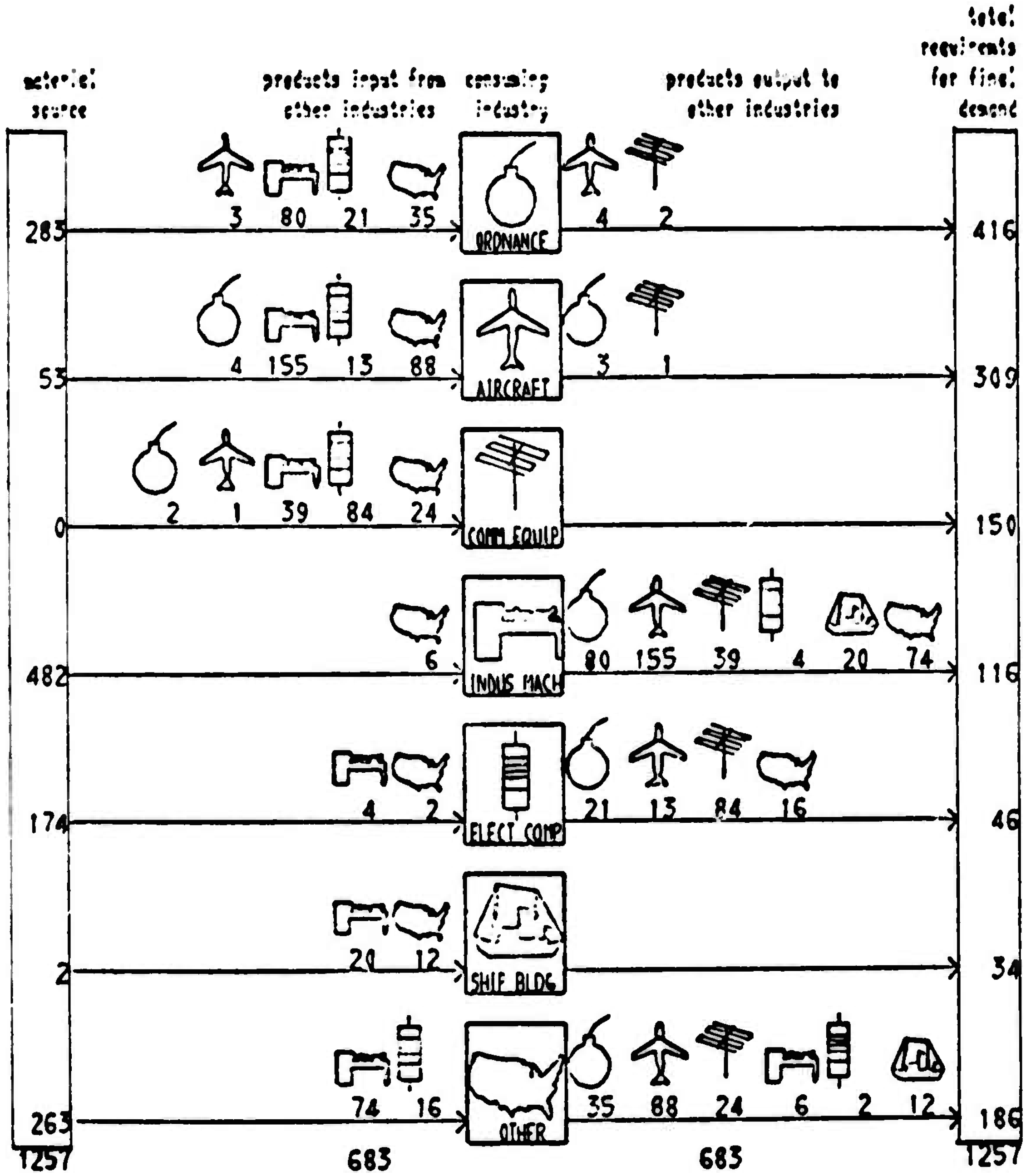


FIGURE A-24. 1972 TUNGSTEN CONSUMPTION BY THE DOD
THOUSANDS OF POUNDS

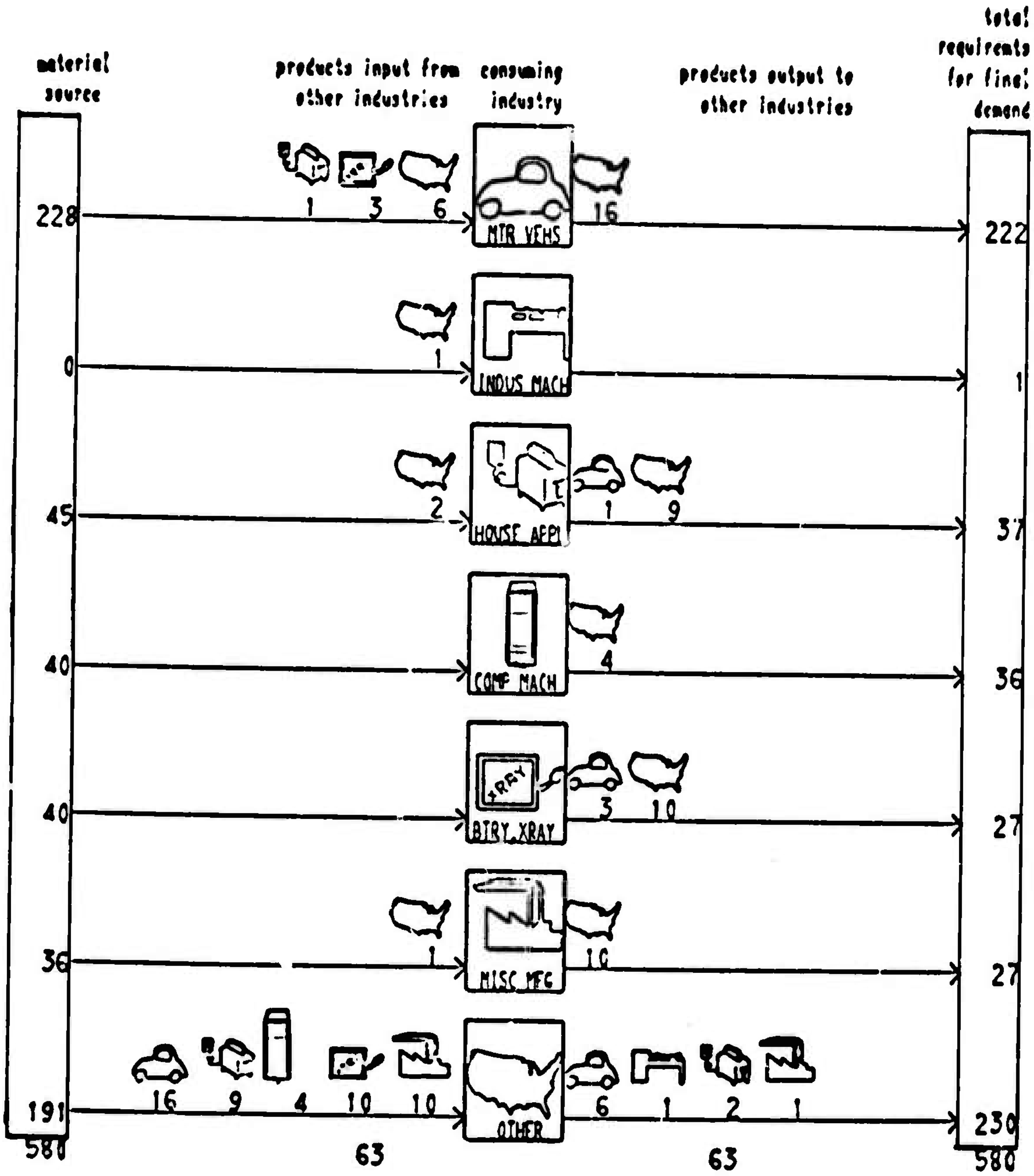


FIGURE A-25. 1972 CAST.ZINC CONSUMPTION BY THE U.S.
THOUSANDS SHORT TONS

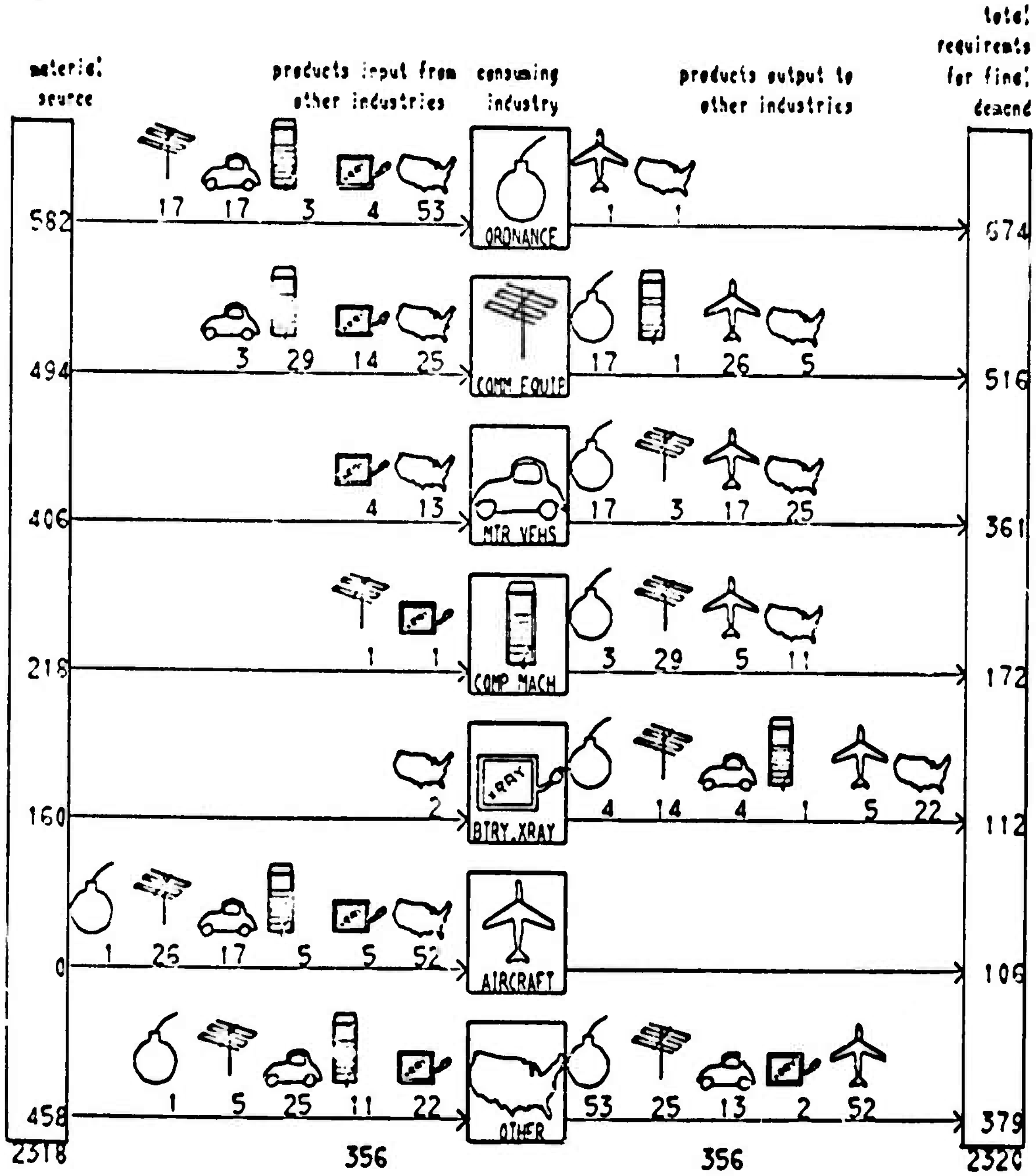


FIGURE A-26. 1972 CAST.ZINC CONSUMPTION BY THE DOD
TENS OF SHORT TONS

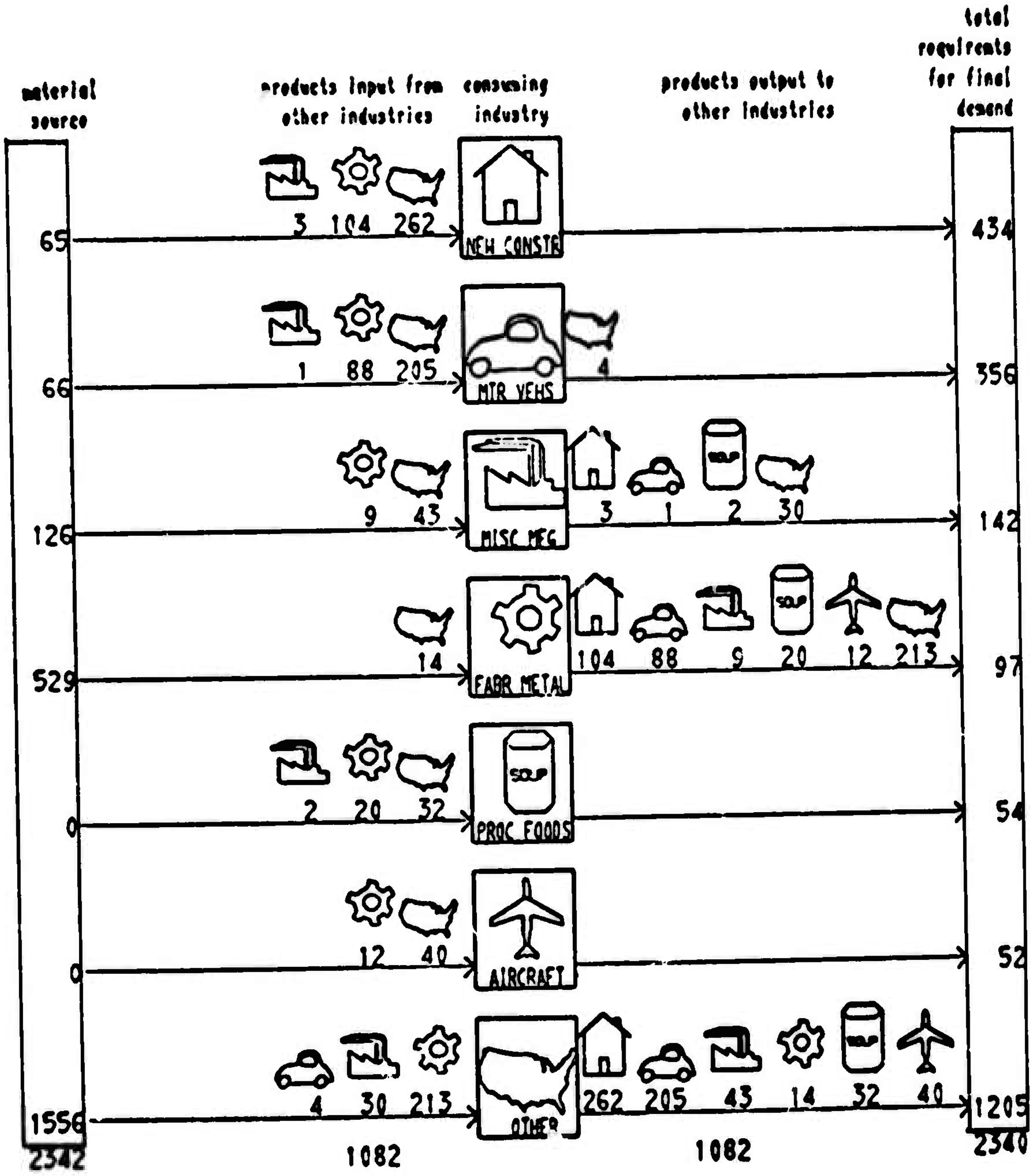


FIGURE A-27. 1972 GALV.ZINC CONSUMPTION BY THE US.
THOUSANDS SHORT TONS

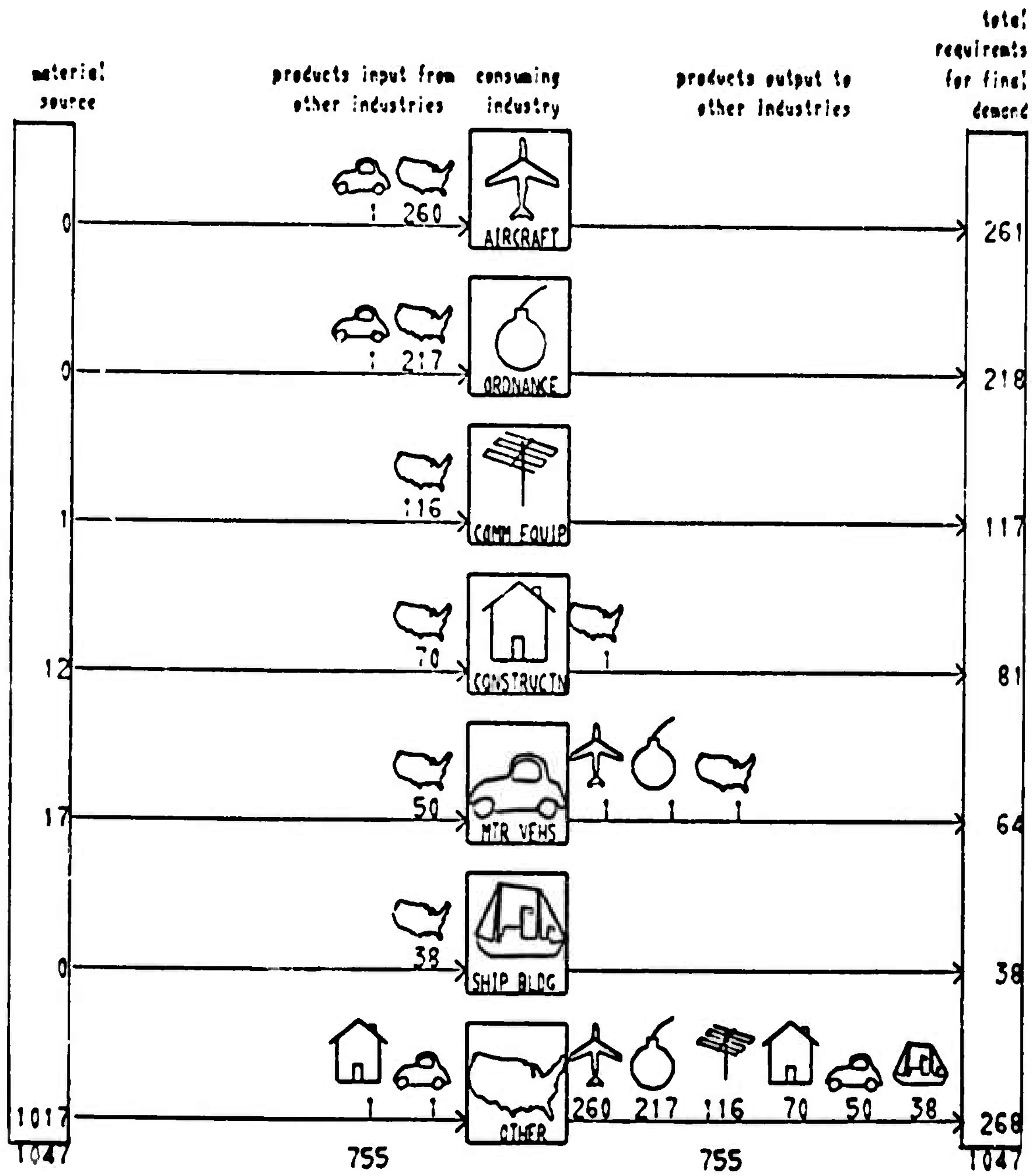


FIGURE A-28. 1972 GALV.ZINC CONSUMPTION BY THE DOD
HUNDREDS SHORT TONS

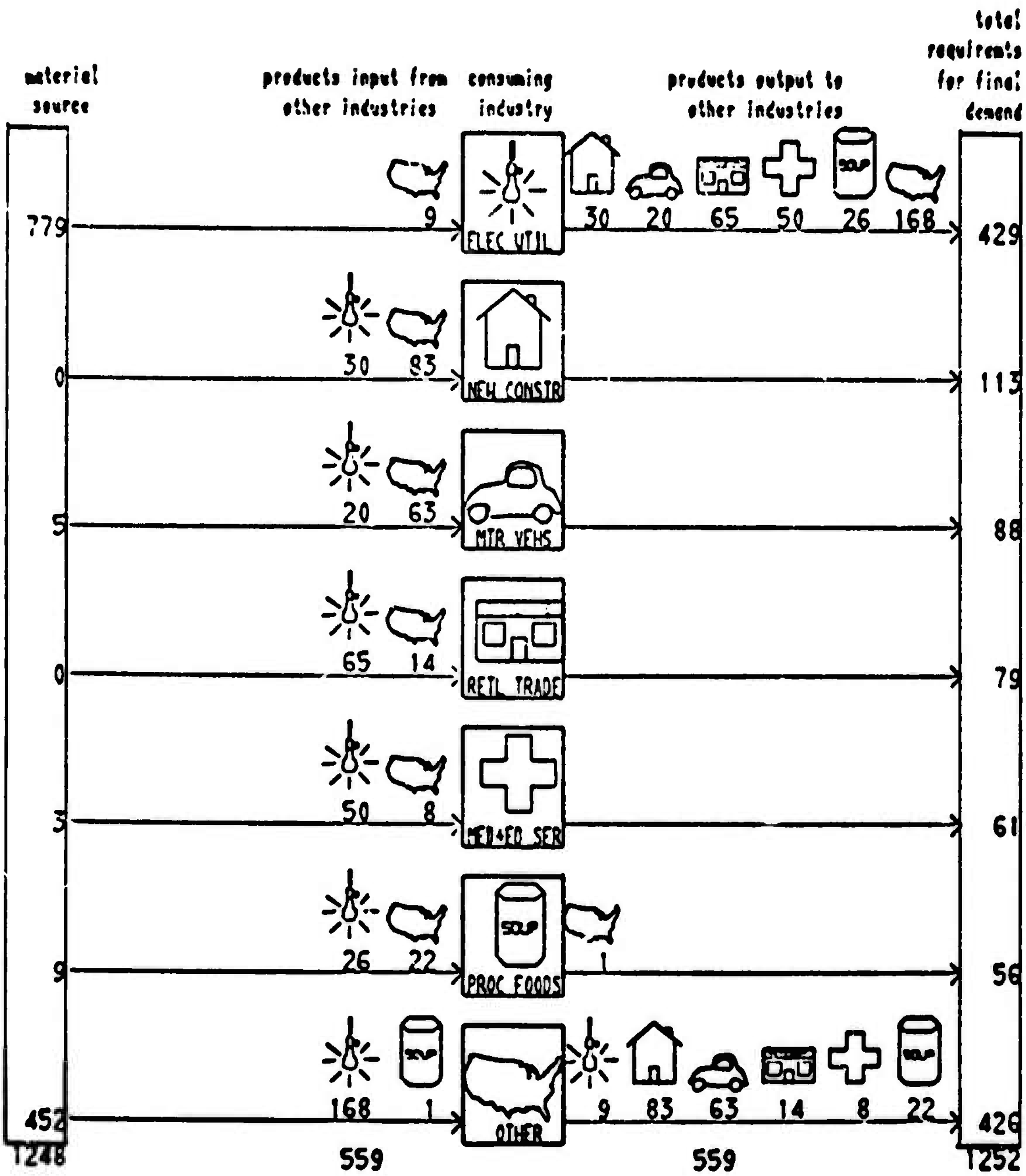


FIGURE A-29. 1972 COAL CONSUMPTION BY THE U.S.
TEN TRILLION BTU

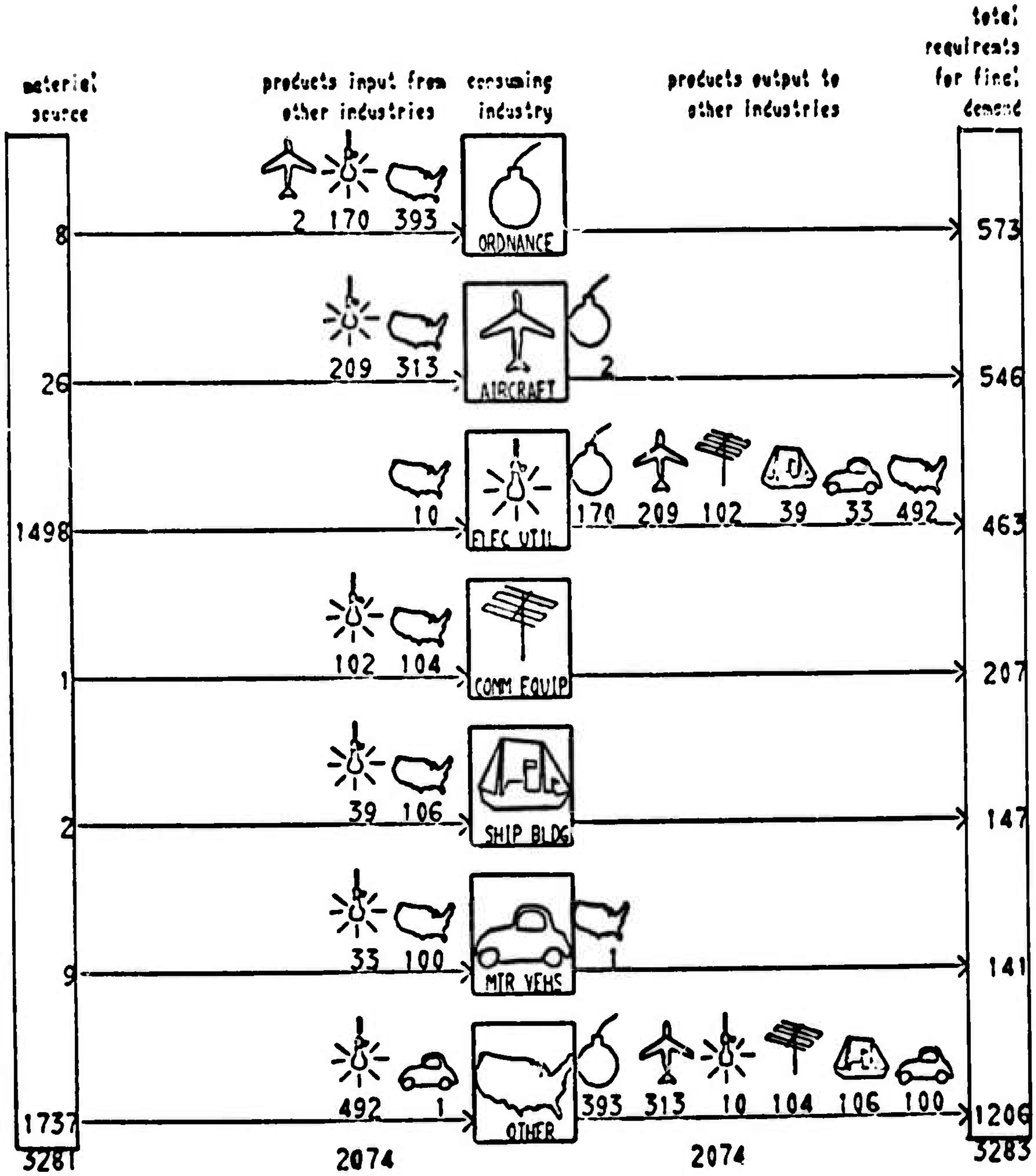


FIGURE A-30. 1972 COAL CONSUMPTION BY THE DOD
HUNDRED BILLION BTU

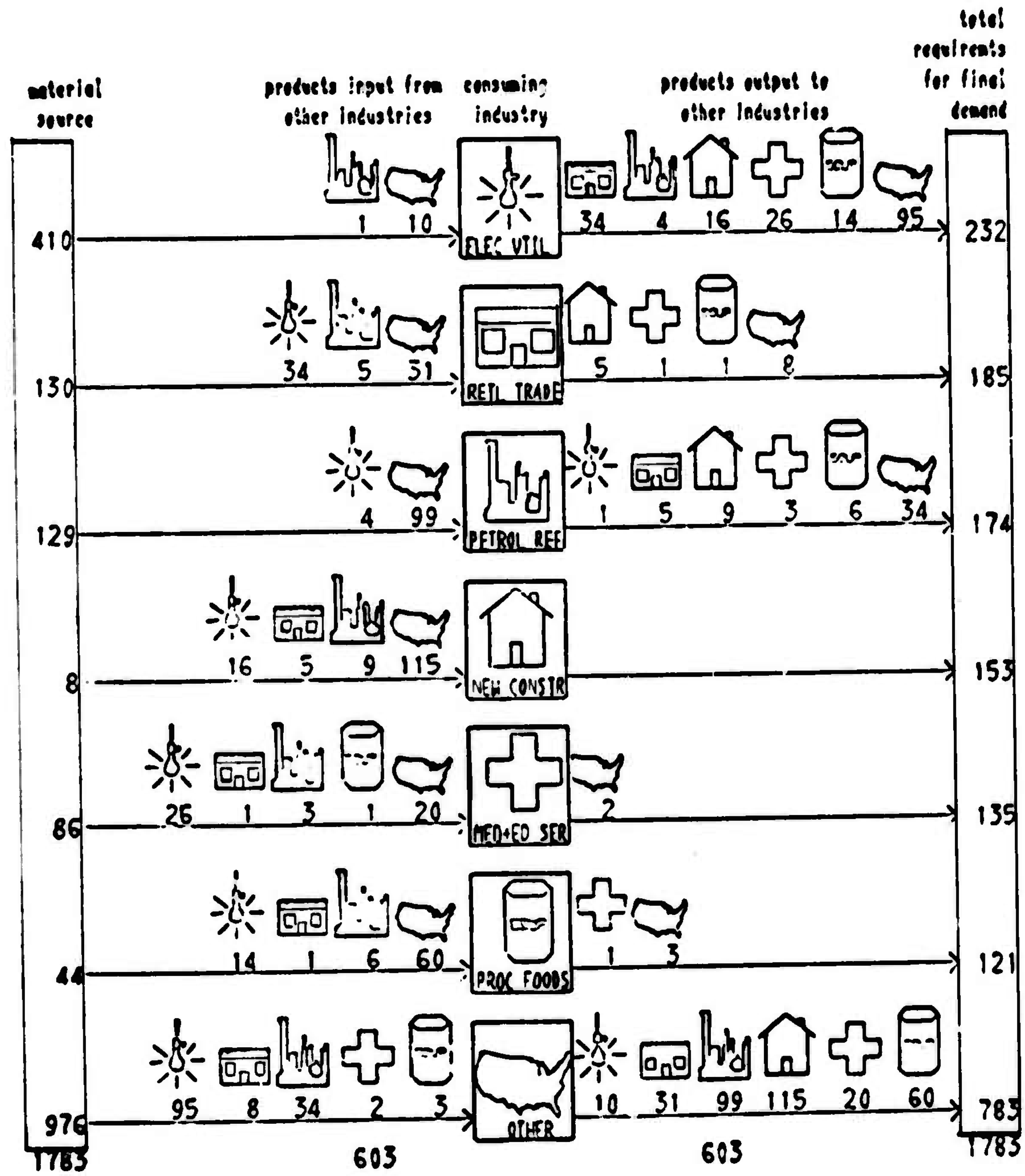


FIGURE A-31. 1972 NAT. GAS CONSUMPTION BY THE US.
TEN TRILLION BTU

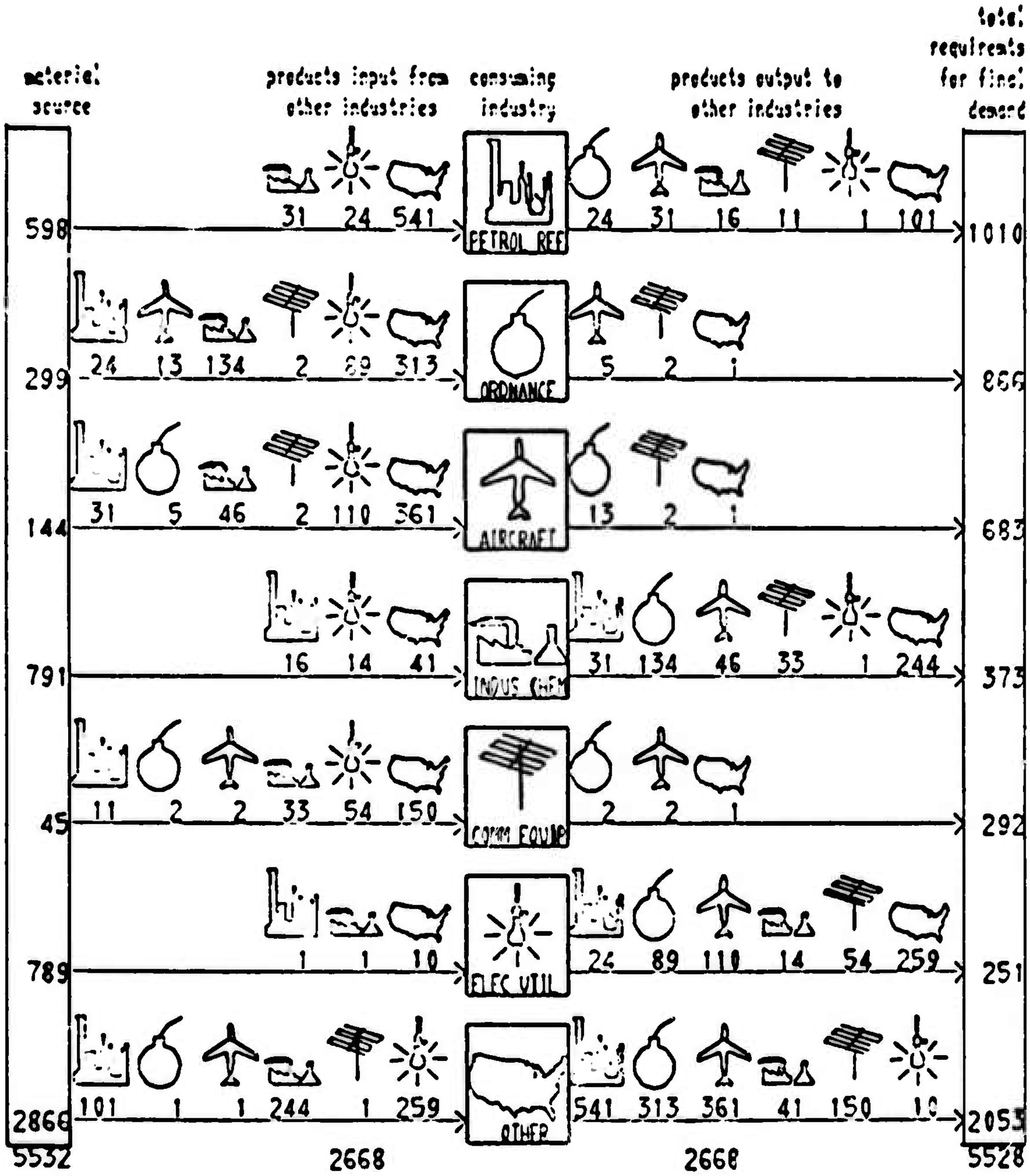


FIGURE A-32. 1972 NAT. GAS CONSUMPTION BY THE DOD
HUNDRED BILLION BTU

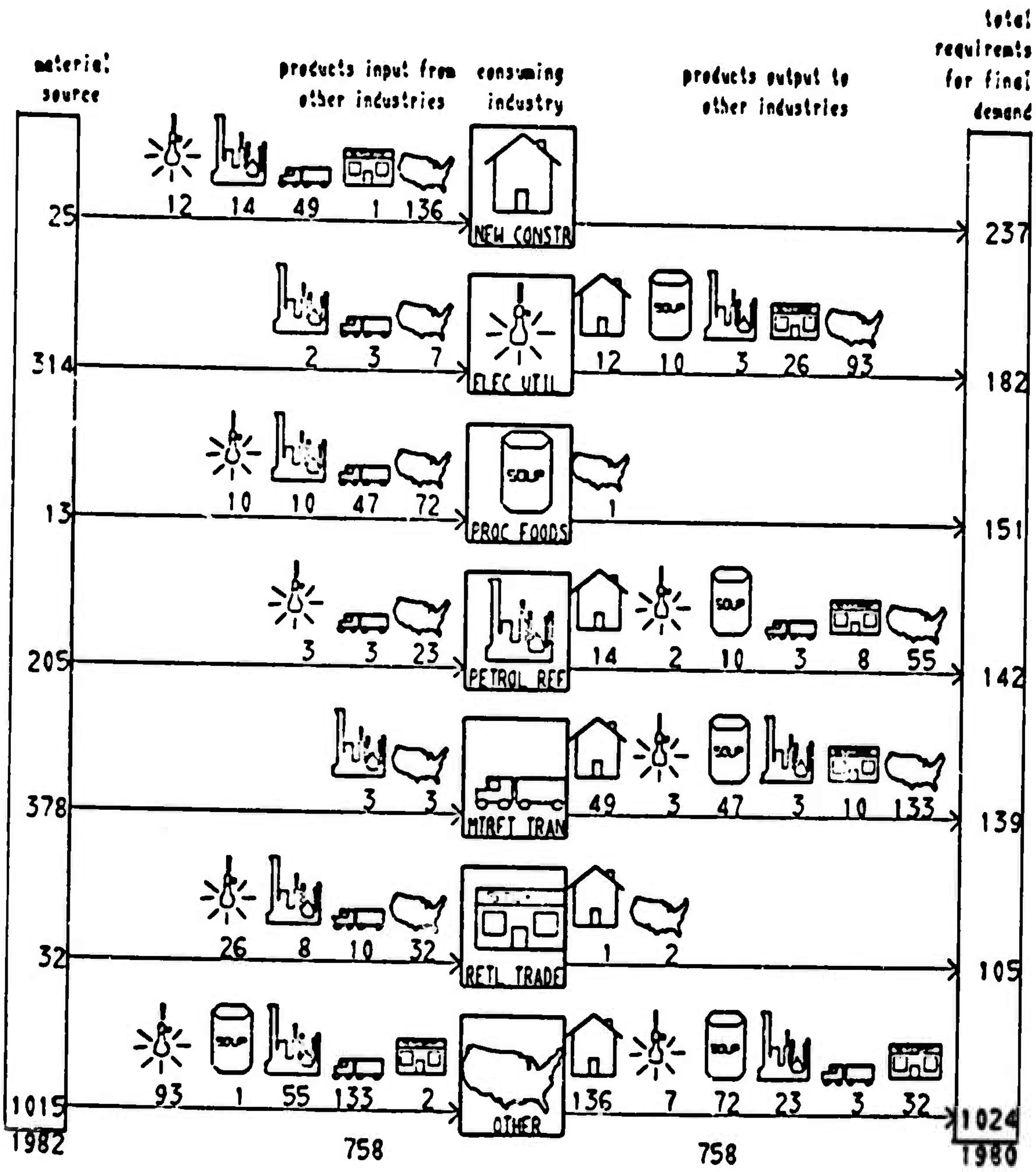


FIGURE A-33. 1972 PETROLEUM CONSUMPTION BY THE U.S.
TEN TRILLION BTU

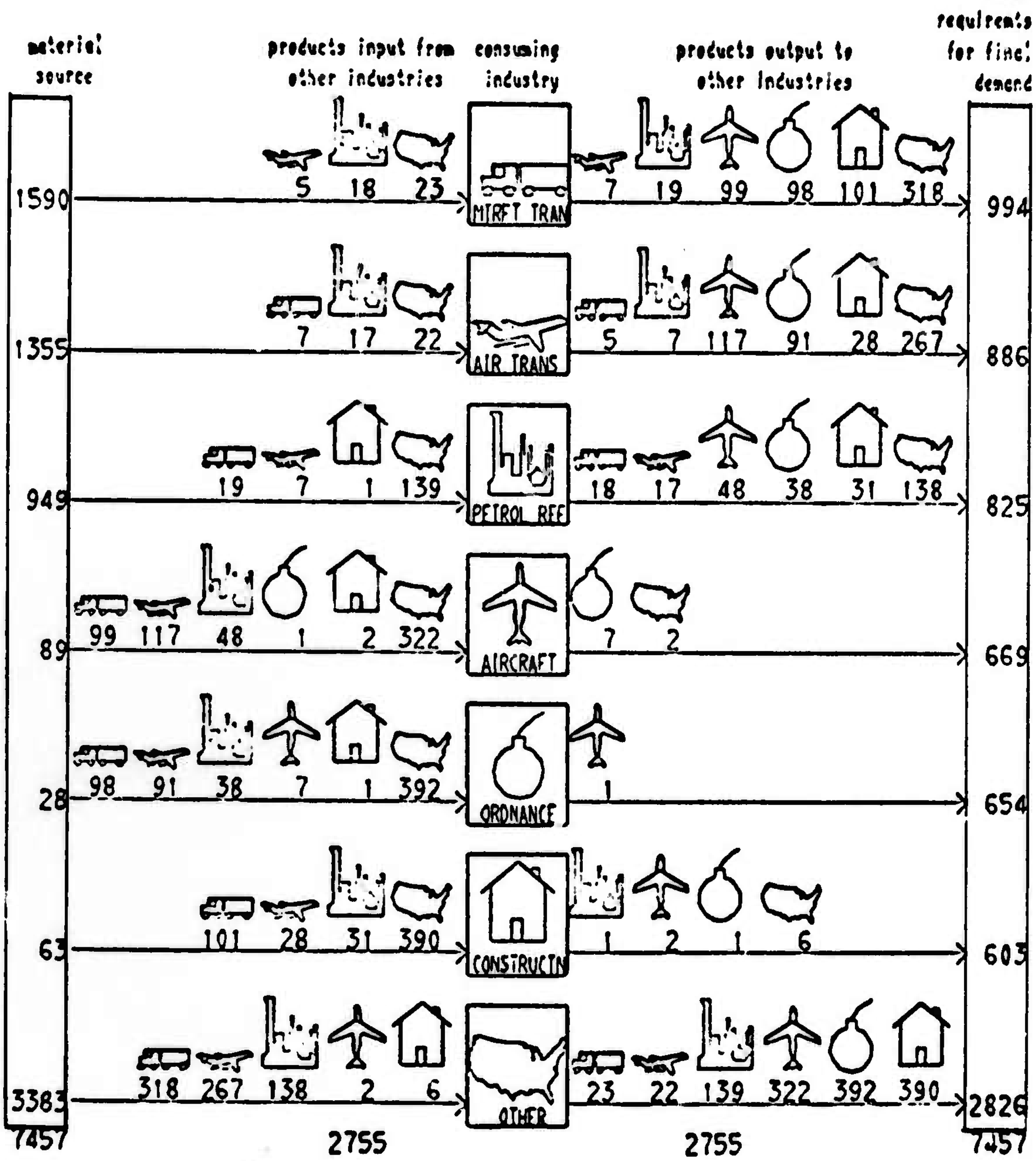


FIGURE A-34. 1972 PETROLEUM CONSUMPTION BY THE DOD
HUNDRED BILLION BTU

3. Circle Diagrams

Figures A-35 through A-51 show the U.S. and DoD consumption of each of the 17 materials for the highest consuming final demands. These figures are also explained in detail in the body of the report.

4. Tables of High Shadow Price Sectors

Table A-5 lists the five final demand sectors having the highest shadow prices during a shortage of each of the 17 materials. The units of shadow price in dollars, increase in GNP per dollar reduction in final demand. The interpretation of this listing is described in the main body of the report for aluminum and petroleum.

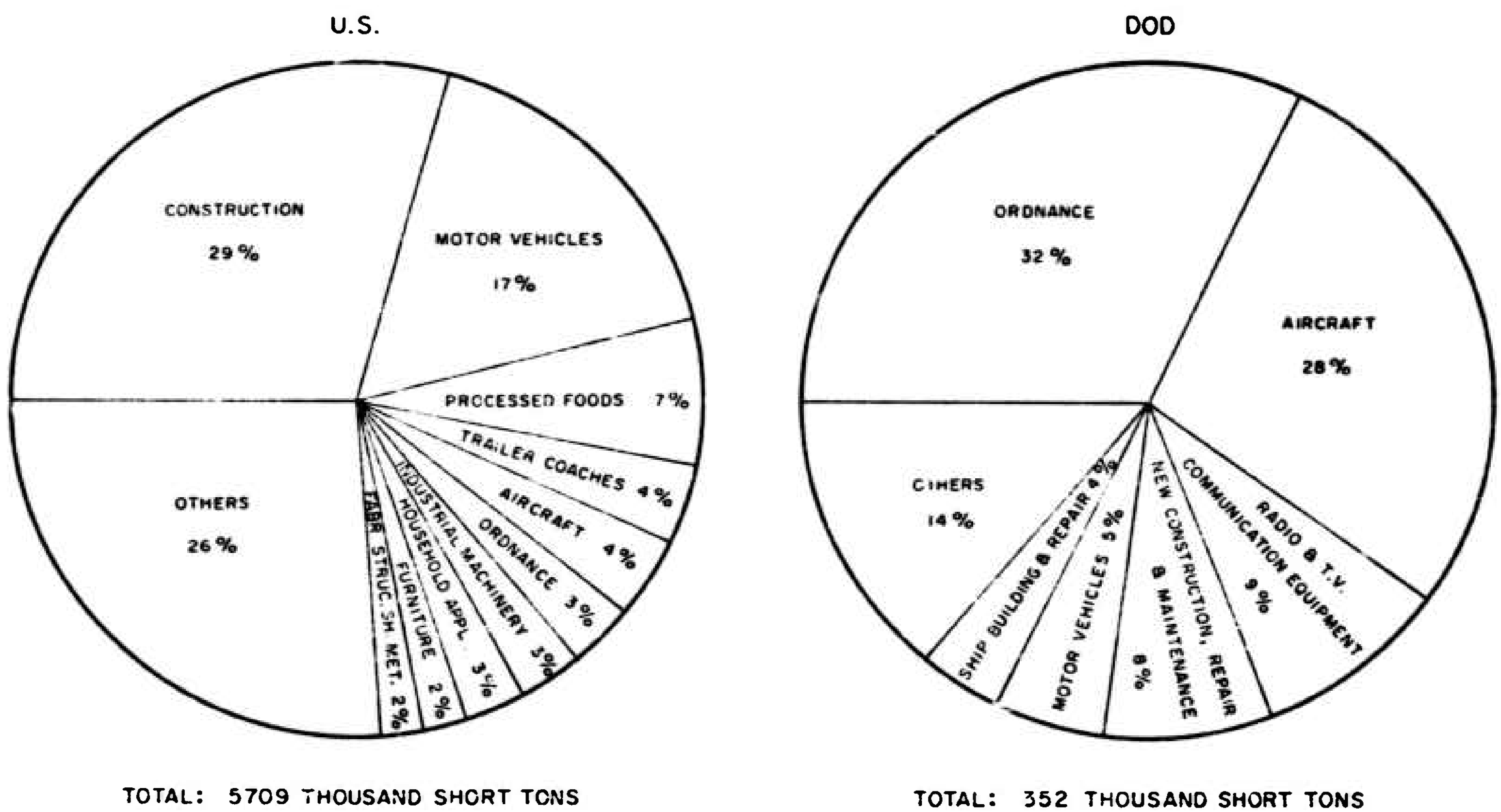


FIGURE A-35. U.S. AND DOD CONSUMPTION OF ALUMINUM BY END USE (1972)

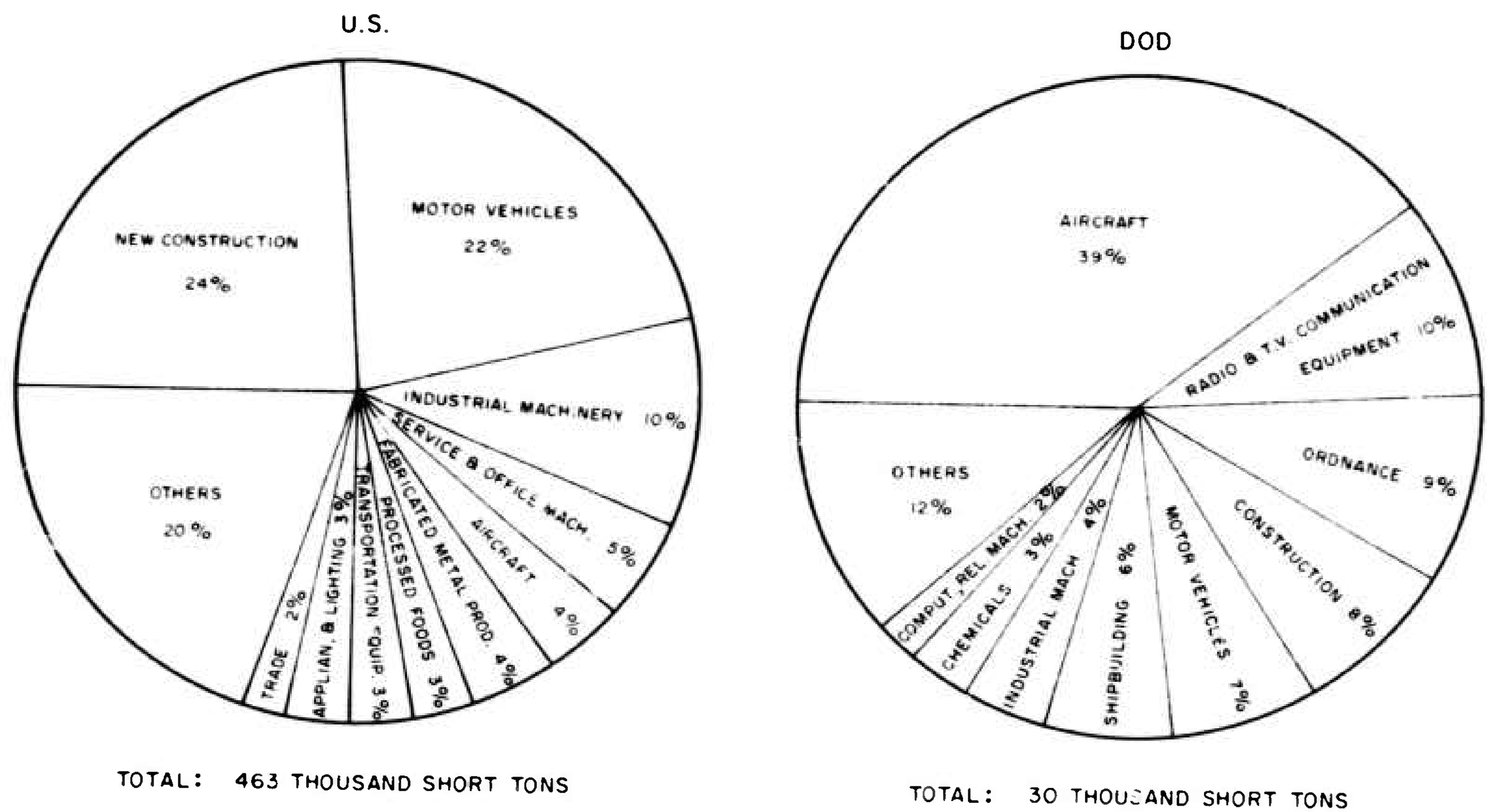


FIGURE A-36. U.S. AND DOD CONSUMPTION OF CHROMIUM BY END USE (1972)

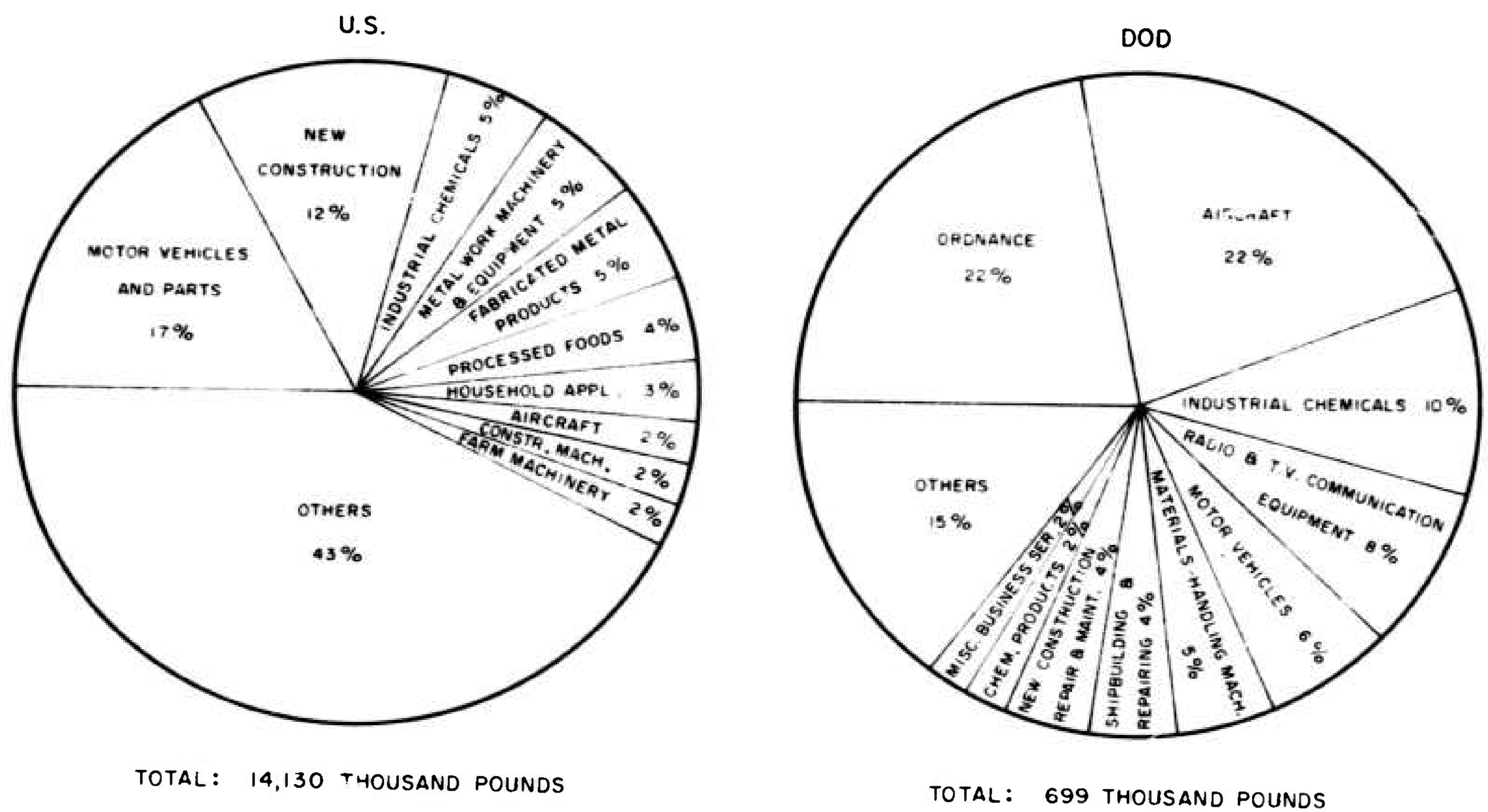
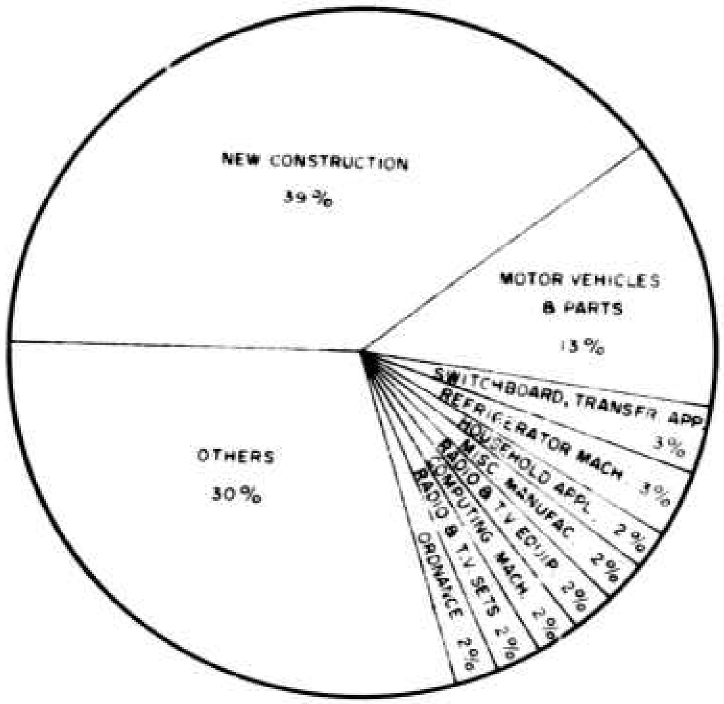


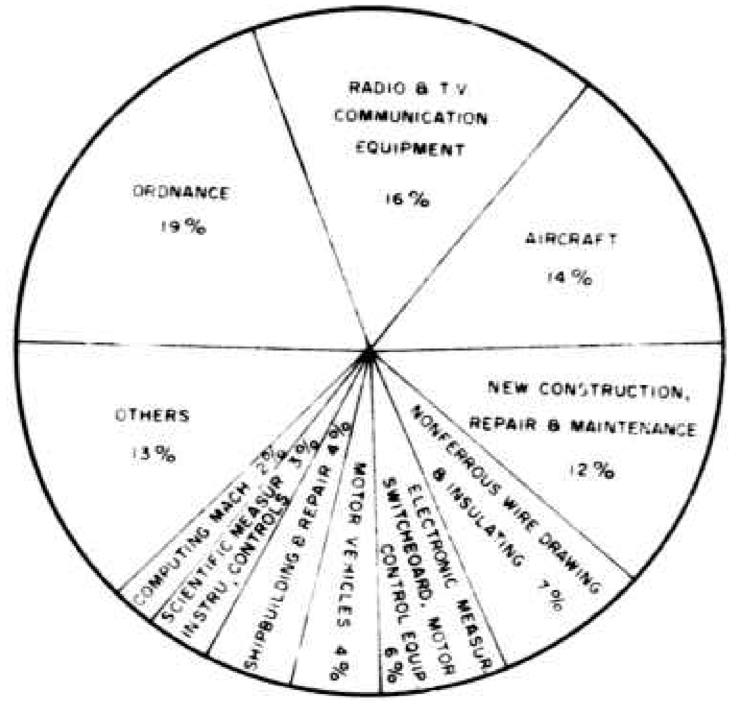
FIGURE A-37. U.S. AND DOD CONSUMPTION OF COBALT BY END USE (1972)

U.S.



TOTAL: 3299 THOUSAND SHORT TONS

DOD

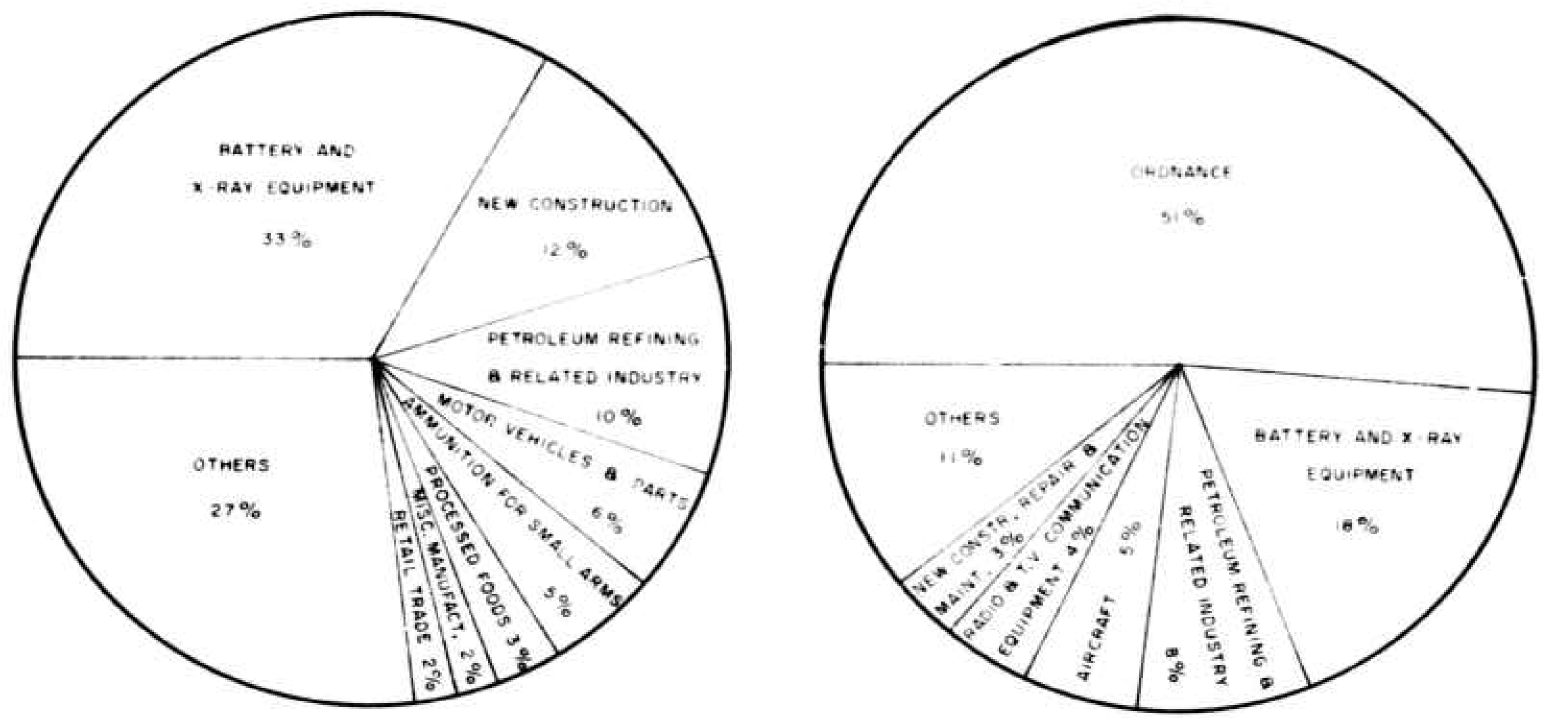


TOTAL: 176 THOUSAND SHORT TONS

FIGURE A-38. U.S. AND DOD CONSUMPTION OF COPPER BY END USE (1972)

U.S.

DOD



TOTAL: 1485 THOUSAND SHORT TONS

TOTAL: 114 THOUSAND SHORT TONS

FIGURE A-39. U.S. AND DOD CONSUMPTION OF LEAD BY END USE (1972)

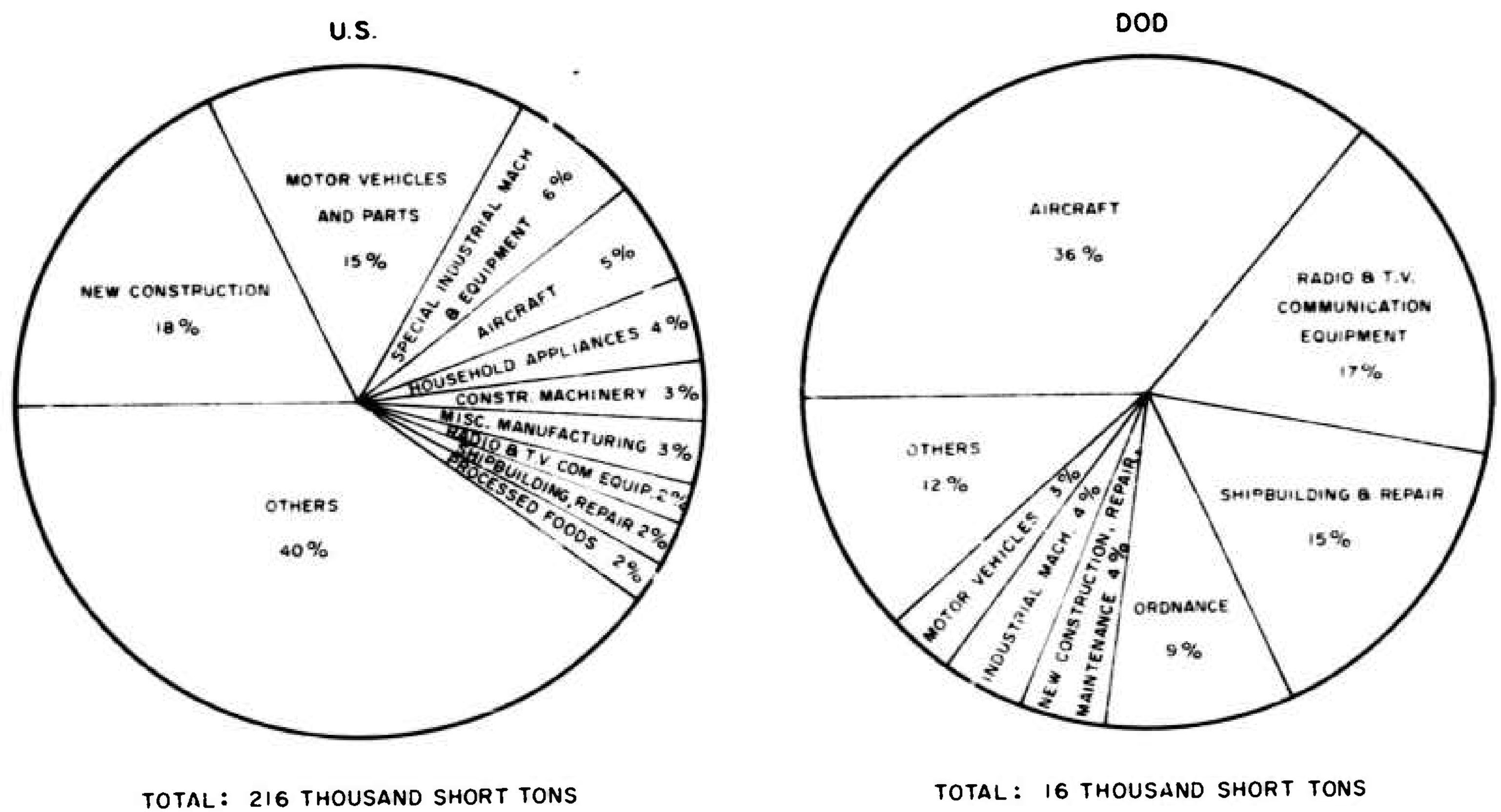
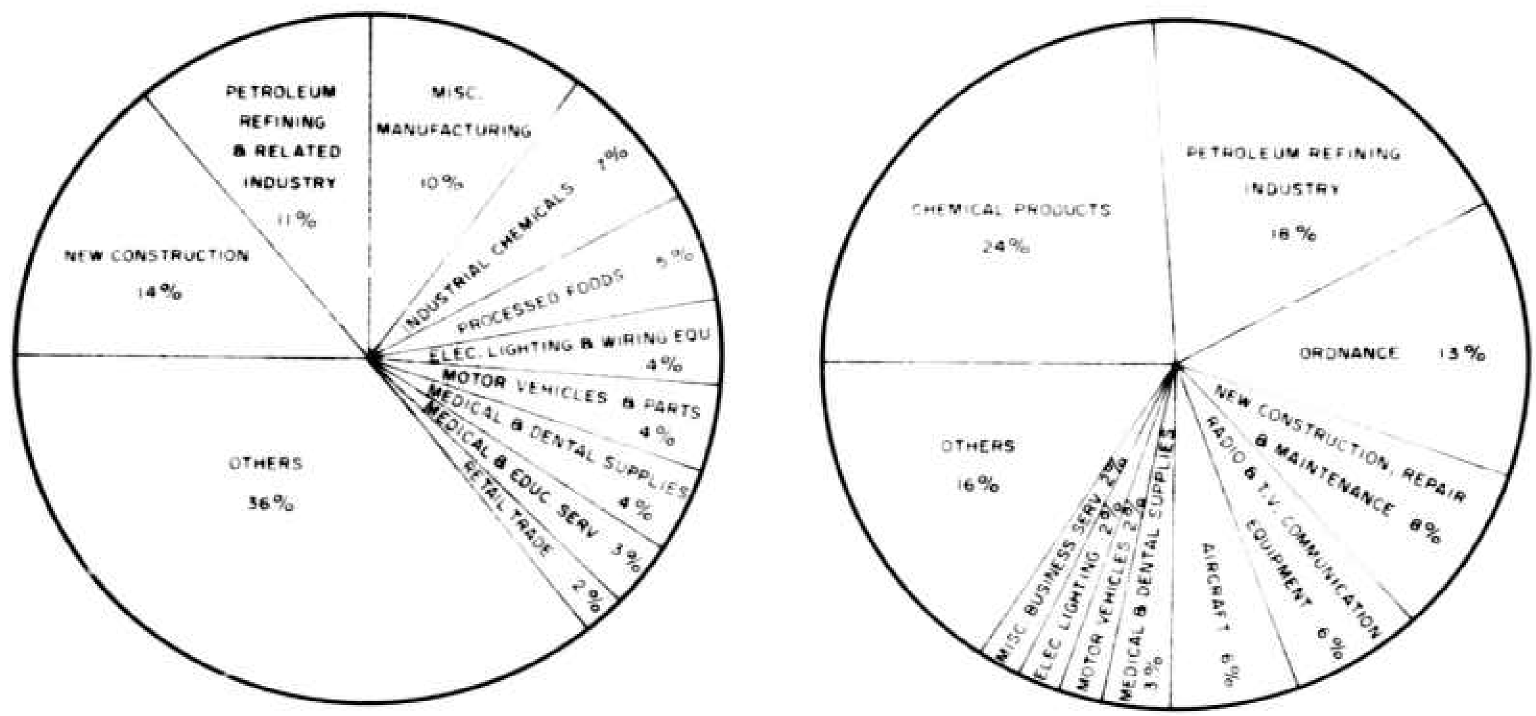


FIGURE A-40. U.S. AND DOD CONSUMPTION OF NICKEL BY END USE (1972)

U.S.

DOD



TOTAL: 543 THOUSAND TROY OUNCES

TOTAL: 19.5 THOUSAND TROY OUNCES

FIGURE A-41. U.S. AND DOD CONSUMPTION OF PLATINUM BY END USE (1972)

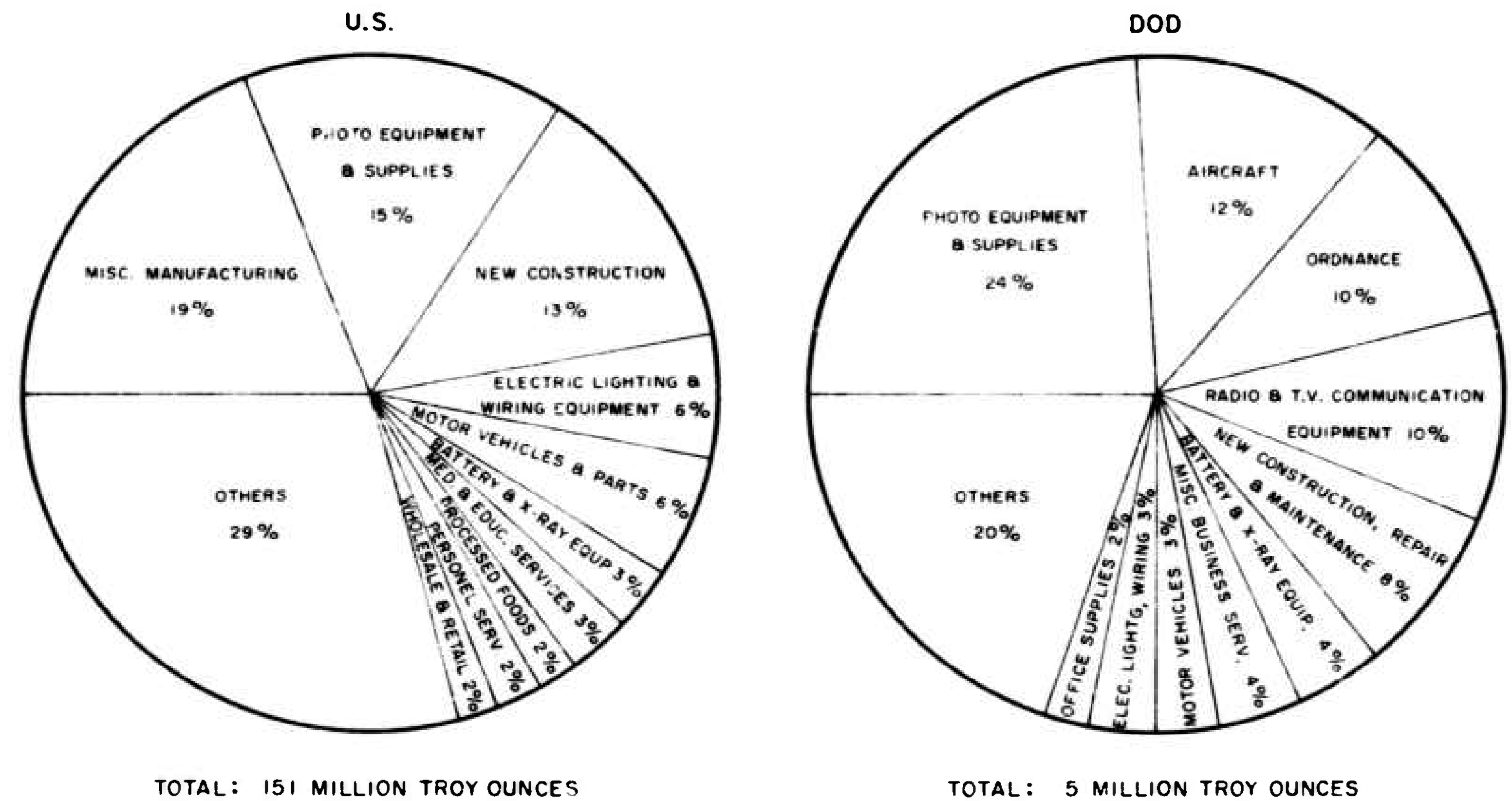
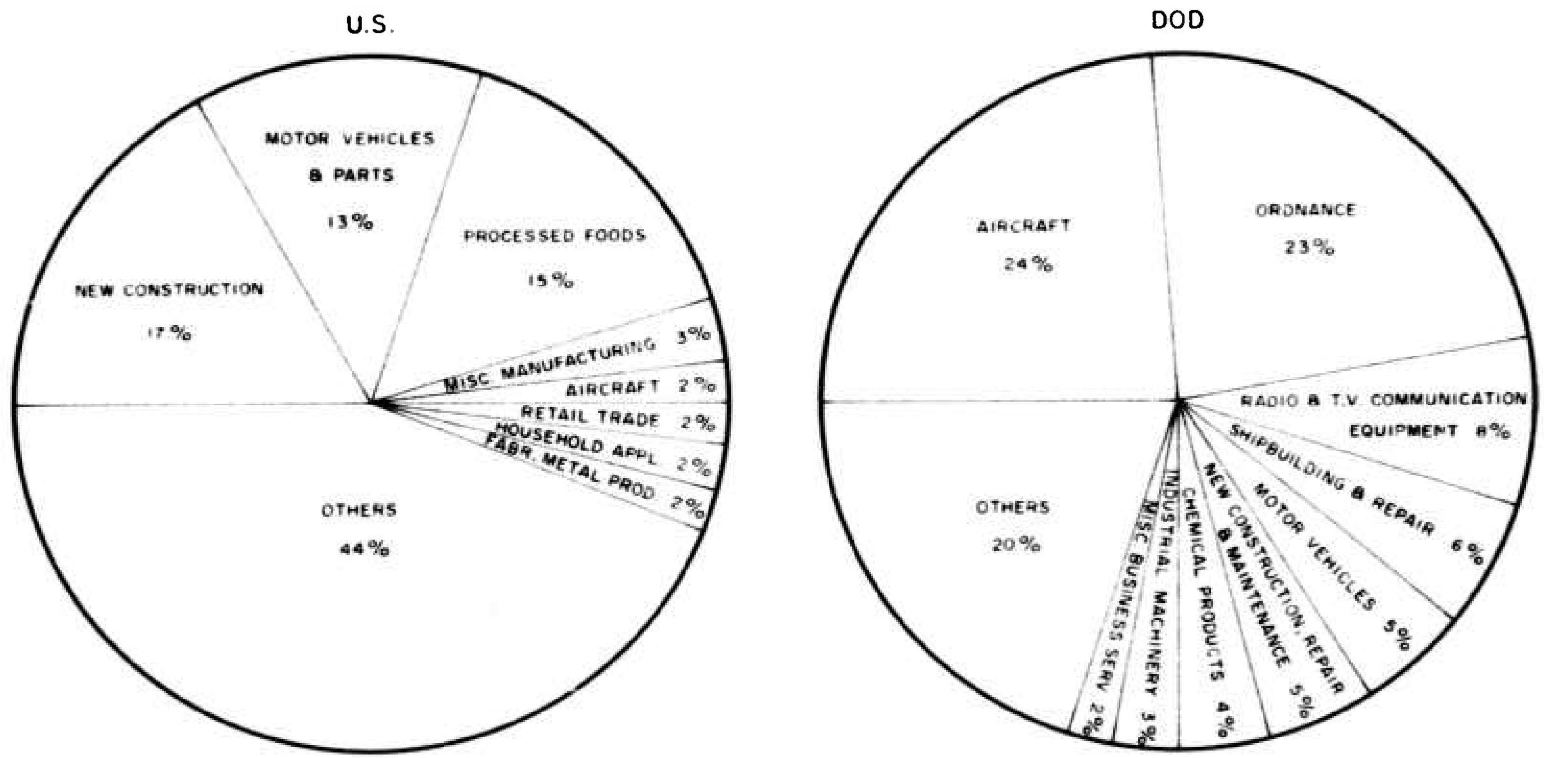


FIGURE A-42. U.S. AND DOD CONSUMPTION OF SILVER BY END USE (1972)



TOTAL: 89,164 LONG TONS

TOTAL: 3985 LONG TONS

FIGURE A-43. U.S. AND DOD CONSUMPTION OF TIN BY END USE (1972)

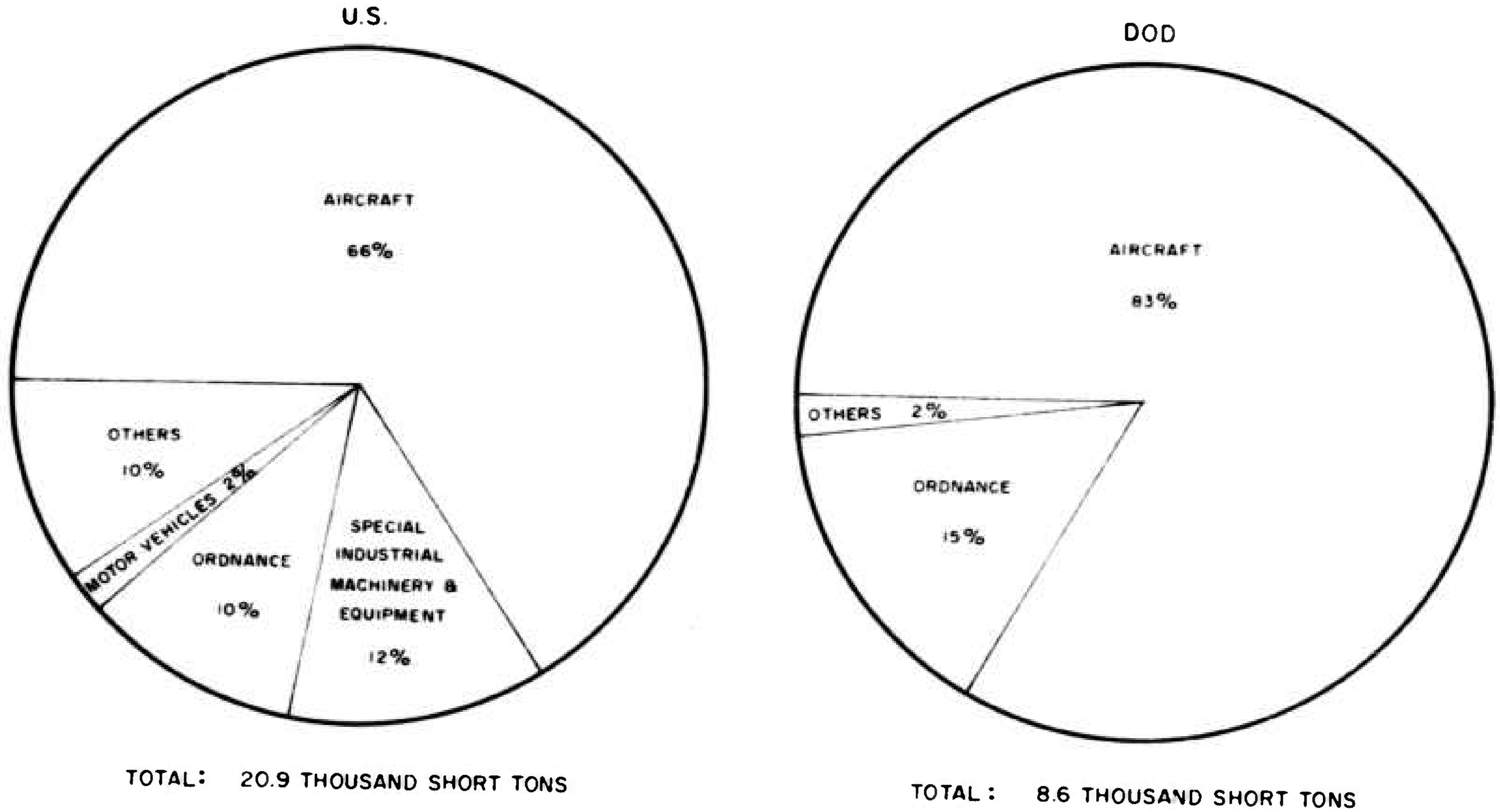
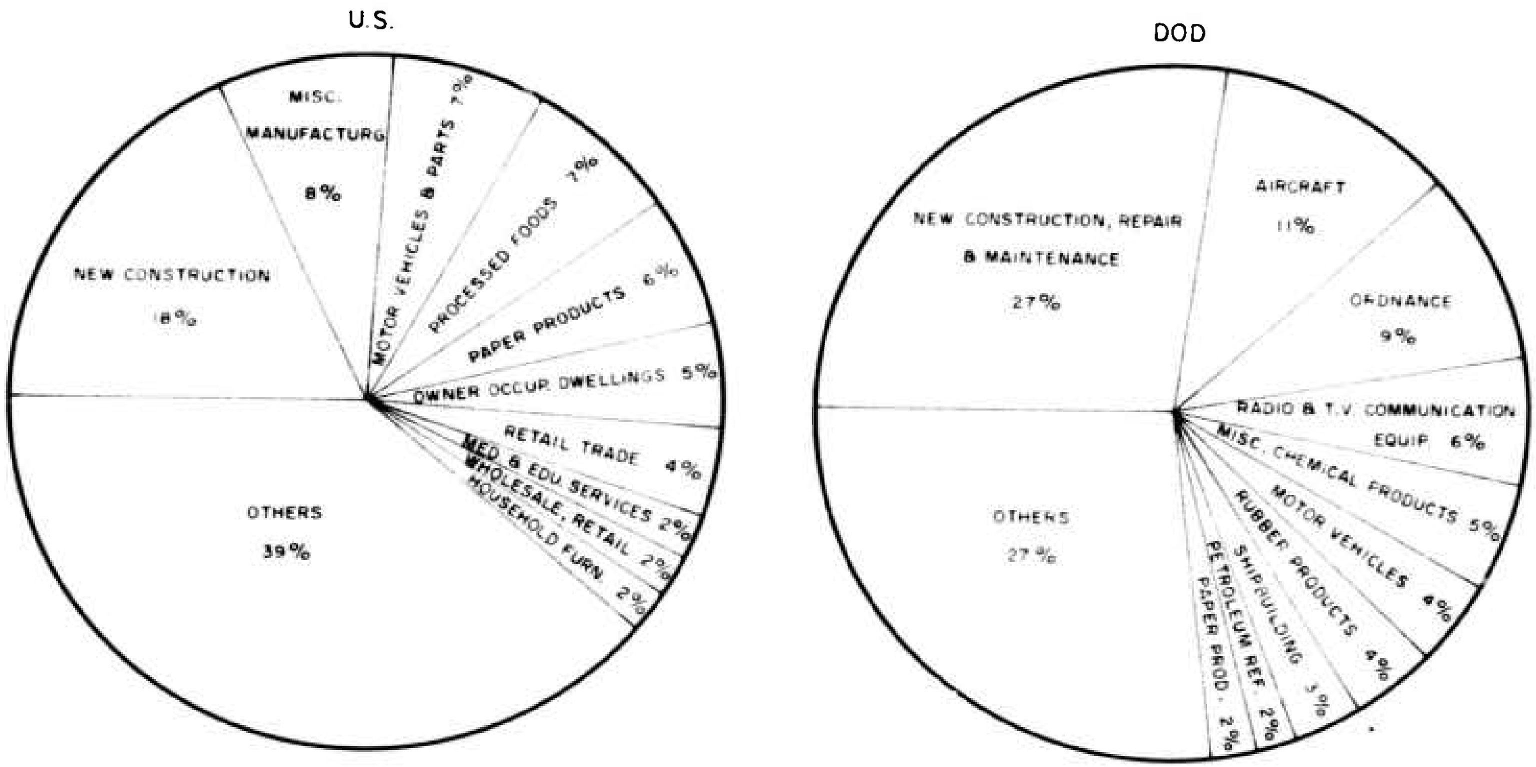


FIGURE A-44. U.S. AND DOD CONSUMPTION OF METALLIC TITANIUM BY END USE (1972)



TOTAL: 830 THOUSAND SHORT TONS

TOTAL: 24 THOUSAND SHORT TONS

FIGURE A-45. US. AND DOD CONSUMPTION OF NON-METALLIC TITANIUM BY END USE (1972)

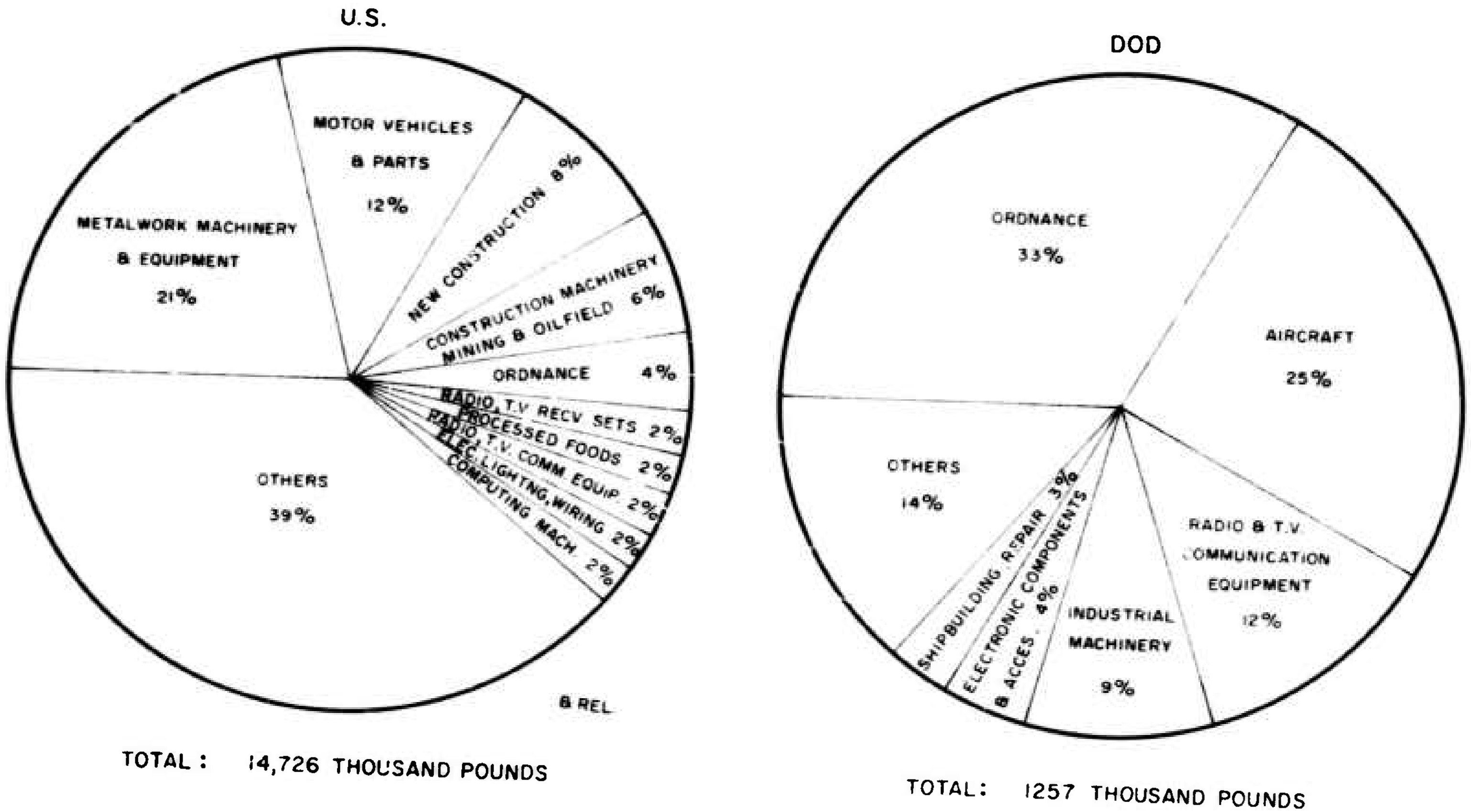
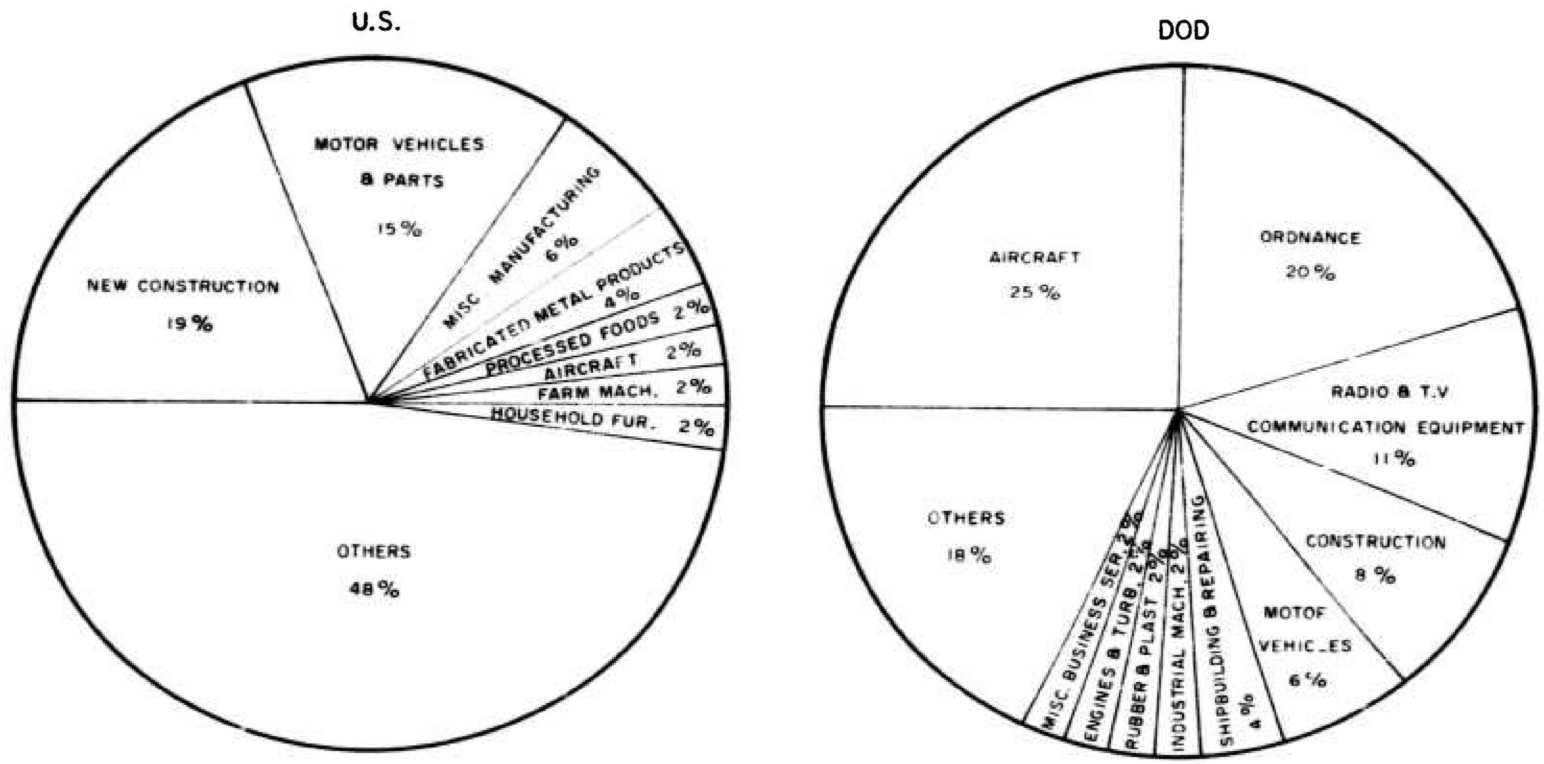


FIGURE A-46. U.S. AND DOD CONSUMPTION OF TUNGSTEN BY END USE (1972)



TOTAL: 2,342 THOUSAND SHORT TONS

TOTAL: 105 THOUSAND SHORT TONS

FIGURE A-47. U.S. AND DOD CONSUMPTION OF GALVANIZED ZINC BY END USE (1972)

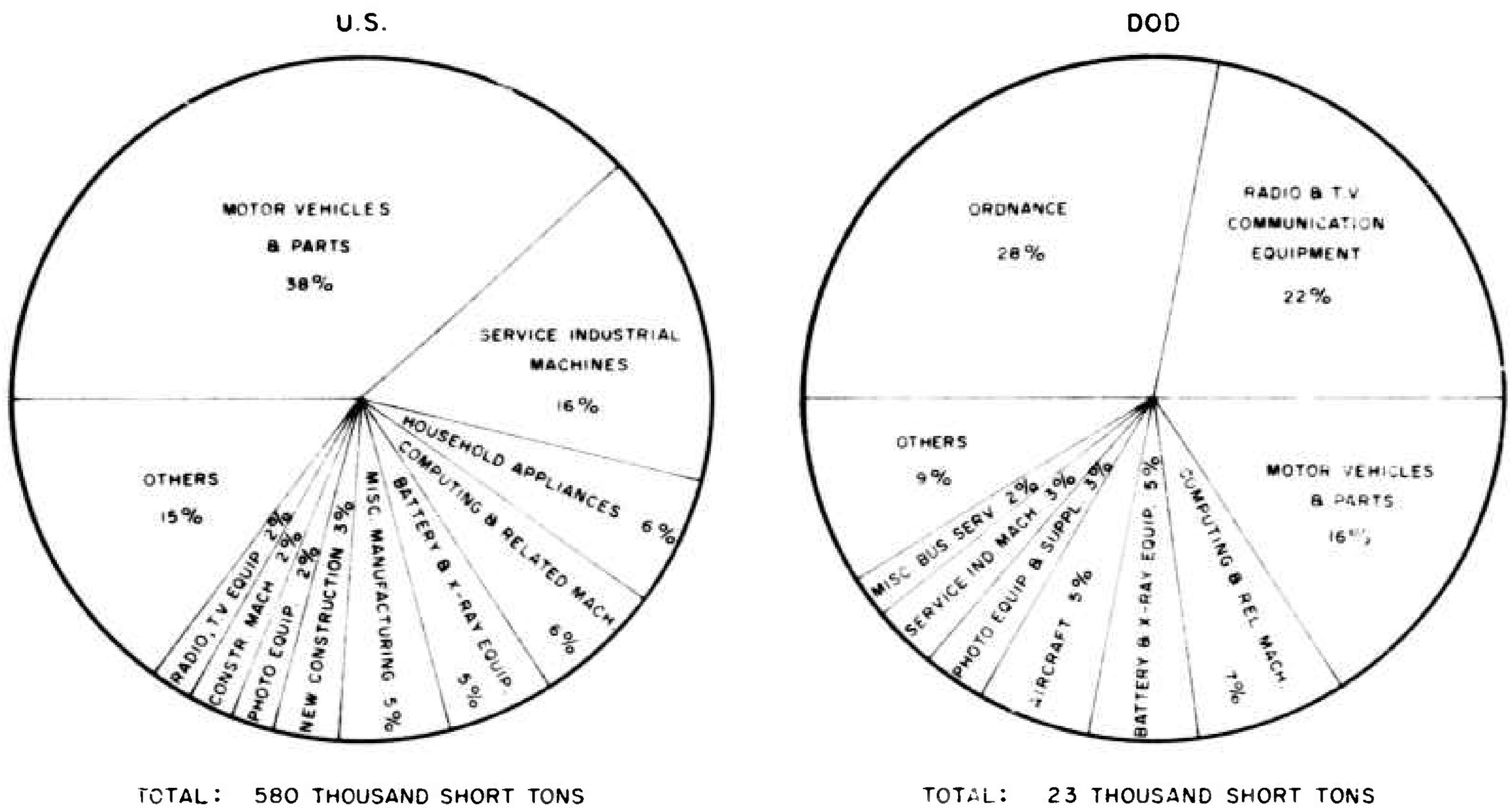
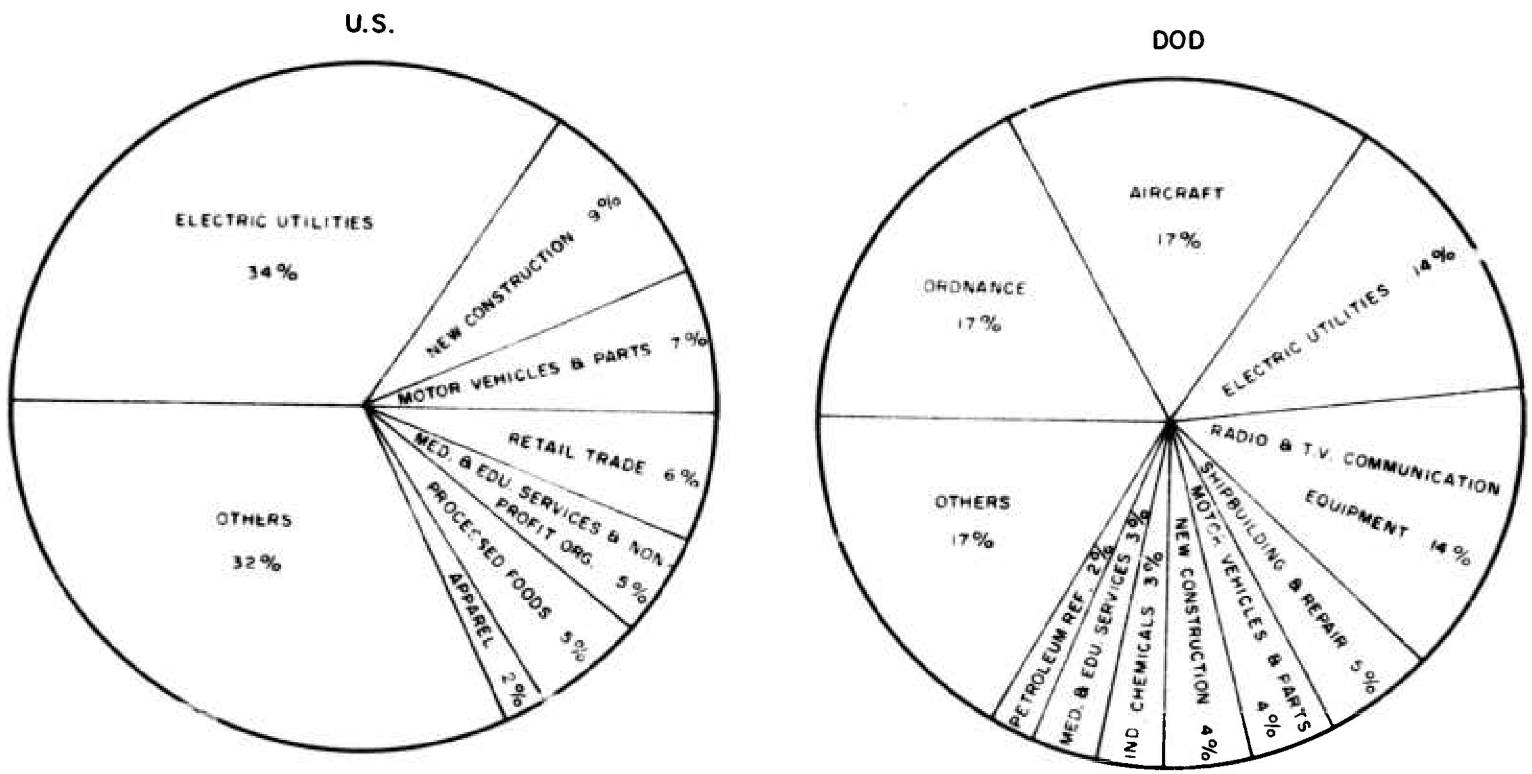


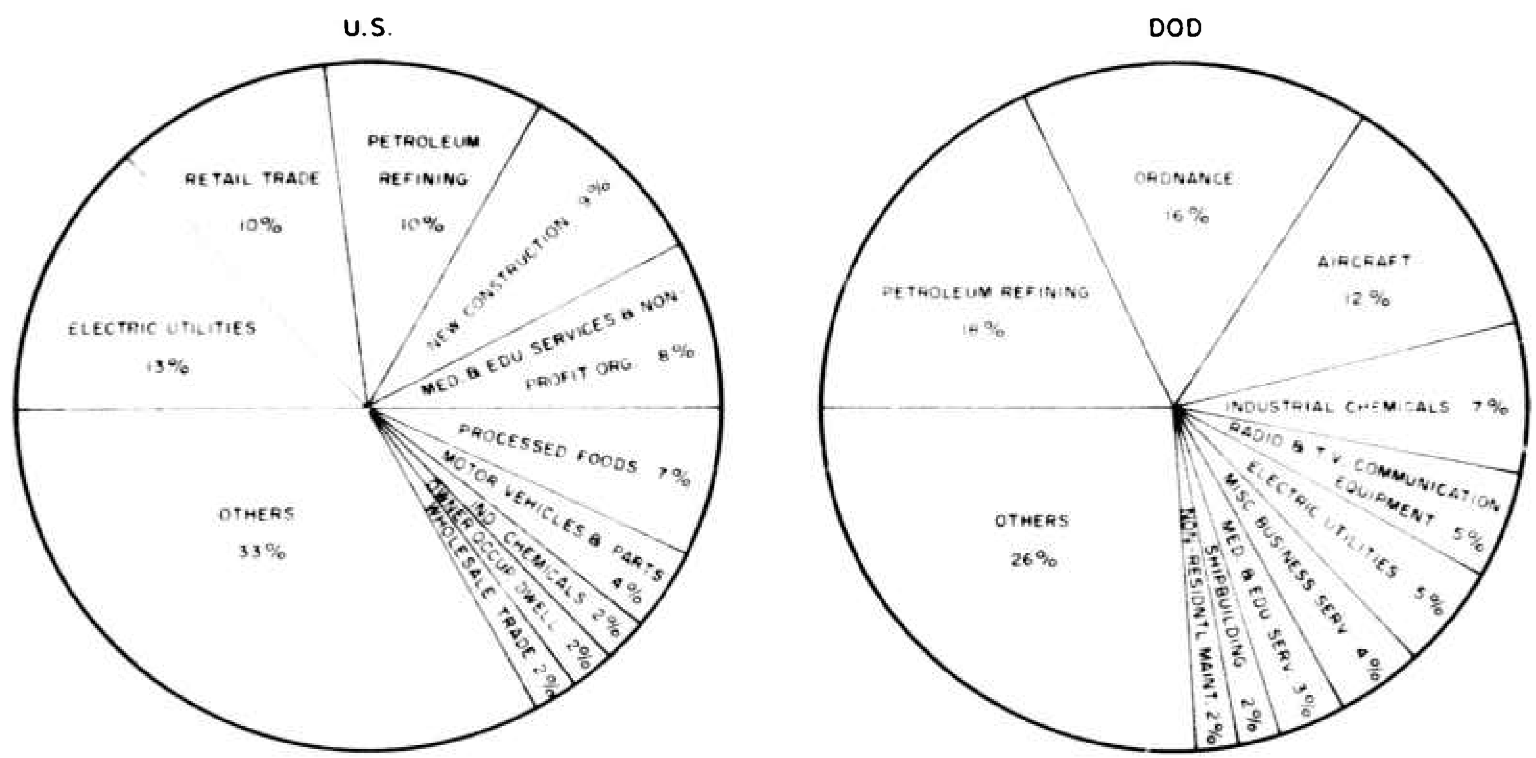
FIGURE **A-48**. U.S. AND DOD CONSUMPTION OF CAST ZINC BY END USE (1972)



TOTAL: 12,496 TRILLION BTU'S

TOTAL: 328 TRILLION BTU'S

FIGURE A-49. U.S. AND DOD CONSUMPTION OF COAL BY END USE (1972)



TOTAL: 17,840 TRILLION BTU'S

TOTAL: 553 TRILLION BTU'S

FIGURE A-50. U.S. AND DOD CONSUMPTION OF NATURAL GAS BY END USE (1972)

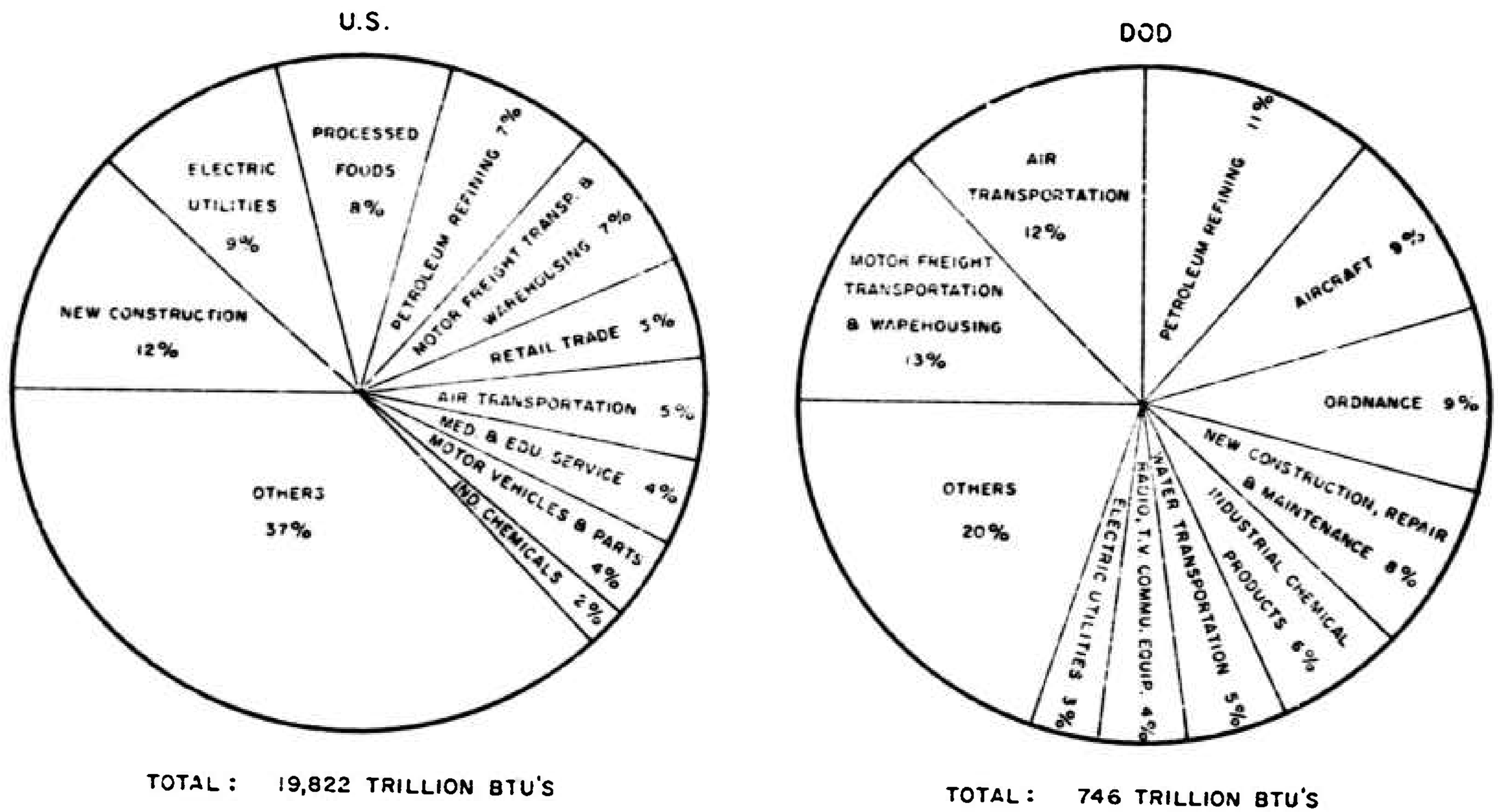


FIGURE A-51. U.S. AND DOD CONSUMPTION OF PETROLEUM BY END USE (1972)

Table A-5

FINAL DEMANDS WITH THE HIGHEST SHADOW PRICES IN A SHORTAGE

Material	Final Demand Sectors		Shadow Price at a Shortage of	
	No.	Name	30%	20%
Aluminum	19	Fabricated metal products	43	2
	27	Transportation equipment	30	2
	9	Ordnance	18	2
	23	Appliances and lighting	17	1
	25	Motor vehicles	16	1
			30%	20%
Chromium	19	Fabricated metal products	34	3
	17	Rubber, leather, glass and clay	17	1
	20	Engines and industrial machinery	17	1
	25	Motor vehicles	17	1
	22	Computers, office and other service machinery	16	1
			30%	20%
Cobalt	12	Chemical products	48	6
	18	Primary and secondary metal products	32	4
	19	Fabricated metal products	31	4
	20	Engines and industrial machinery	18	2
	14	Paints and allied products	14	2

Table A-5 (continued)

Material	Final Demand Sectors No.	Name	Shadow Price at a Shortage of	
			30%	20%
Copper	23	Appliances and electric lighting	16	1
	22	Computers, office and other service machinery	12	1
	19	Fabricated metal products	12	1
	18	Primary and secondary metal products	12	1
	24	Communication and electrical equipment	9	--
			40%	30%
Lead	24	Communication and electrical equipment	42	7
	14	Paints and allied products	17	22
	9	Ordnance	17	3
	15	Petroleum refining	13	2
	18	Primary and secondary metal products	6	1
			30%	20%
Nickel	21	Machine shop products	14	1
	19	Fabricated metal products	14	1
	20	Engines and industrial machinery	10	1
	23	Appliances and electric lighting	8	--
	26	Aircraft	7	--

Table A-5 (continued)

Material	Final Demand Sectors		Shadow Price at a Shortage of	
	No.	Name	25%	20%
Platinum	12	Chemical products	61	24
	23	Appliances and electric lighting	27	10
	28	Instrumens and miscellaneous manufacturing	24	9
	15	Petroleum refining	20	8
	14	Paints and allied products	15	5
			30%	20%
Silver	28	Instruments and miscellaneous manufacturing	59	4
	23	Applinaces and electric lighting	36	2
	19	Fabricated metal products	8	1
	24	Communication and electrical equipment	7	--
	22	Computers, office and other service machinery	6	--
			30%	20%
Tin	18	Primary and secondary metal products	59	4
	19	Fabricated metals products	41	3
	27	Other transportation equipment	14	1
	25	Motor vehicles	13	--
	20	Engines and industrial machinery	12	--

Table A-5 (continued)

Material	Final Demand Sectors		Shadow Price at a Shortage of	
	No.	Name	45%	30%
Metallic Titanium	26	Aircraft	159	--
	9	Ordnance	47	--
	16	Paving and asphalt materials	28	--
	20	Engines and industrial machinery	17	--
	21	Machine shop products	1	--
			25%	20%
Nonmetallic Titanium	14	Paints and allied products	422	290
	13	Plastic, rubber and cellulose	12	8
	28	Instruments and miscellaneous manufacturing	11	7
	11	Textiles and paper products	8	5
	8	Construction	7	4
			40%	20%
Tungsten	20	Engines and industrial machinery	116	1
	9	Ordnance	28	--
	23	Applinaces and electric lighting	28	--
	24	Communication and electrical equipment	21	--
	18	Primary and secondary metal products	20	--
			35%	30%
Zinc Casting	22	Computers, office and other service machinery	105	5
	25	Motor vehicles	47	2
	23	Appliances and electric lighting	27	1
	24	Communication and electrical equipment	26	1
	9	Ordnance	14	--

Table A-5 (concluded)

Material	Final Demand Sectors No.	Name	Shadow Price at a Shortage of	
			20%	10%
Coal	32	Electric utilities	56	12
	3	Anthracite coal	21	4
	18	Primary and secondary metal products	11	2
	4	Bituminous coal	10	2
	12	Chemical products	4	1
			15%	10%
Natural Gas	30	Pipeline transportation	59	49
	7	Natural gas liquid	37	30
	32	Electric utilities	13	11
	6	Natural gas	8	7
	15	Petroleum refining	8	6
			25%	10%
Petroleum	16	Paving and asphalt materials	119	33
	32	Electric utilities	18	5
	12	Chemical products	15	4
	29	Transportation and communication services	13	3
	15	Petroleum refining	11	3